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SPECIAL FEATURES

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TRANSACTIONS

of the

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Vol. II Cleveland, March, 1922 No. 6

TRANSACTIONS ADDS ANOTHER NEW FEATURE

IN THE February issue of TRANSACTIONS appeared for the first time a new department, "Comment and Discussion." That the inauguration of this feature was an improvement to the publication is not questioned, a need for such a column having been felt for some time. Depending upon the support received from Society members and friends, "Comment and Discussion" will appear in every issue of TRANSACTIONS and an attempt will be made to extend its usefulness.

This department is open to general participation, its function being primarily for the discussion and criticism of the articles published in TRANSACTIONS, however, its field is not limited to that alone. Any subject of interest to the Society and its welfare and worthy of comment in a brief way properly comes within the scope of this column. The February and March issues give examples of what can be done in discussing the technical articles. In the interest of greater service, it is hoped the new department will receive active support.

EARLY DISCOVERY OF THE RECALESCENCE POINT IN HEATING STEEL

FOLLOWING is an interesting item concerning the first observation of the recalescence point in the heating of steel. The item is reprinted from a recent issue of *Machinery*.

"In a publication issued in 1778 by one of the industrial associations of that time in Sweden, there is an article on the hardening of steel, written by J. F. Angerstein, in which the author mentions that he has observed a means whereby the correct hardening temperature for steel may be accurately determined. He points out that at the right hardening temperature there is a sudden shadow or lack of brightness in the object being heated. This shadow is evidently caused by the temperature reduction which takes place when the steel passes the recalescence point. It was not possible for the early observer to understand the exact reason for the loss of brightness or shadow in the heated steel, but he had learned that this was the point when the right hardening temperature had been reached, and by observing it he was able to harden at a temperature determined by the same principle as is employed in modern means of determining the recalescence point. It has generally been believed that the earliest observer of this phenomenon was the Russian, Chernoff, who about 1860 called attention to this characteristic of steel when heated. The practical value of these observations was finally clearly laid down by Brinell."

COMMITTEES FOR ANNUAL CONVENTION OF AMERICAN SOCIETY FOR STEEL TREATING

FOLLOWING is given both the national and local committees which have been selected for the annual Convention and Exhibition of the Society, which is to be held in Detroit, Oct. 2 to 7, 1922:

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EFFECT OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF ONE PER CENT CARBON STEEL

By H. J. French and W. George Johnson

DURING 1920 there was brought to the attention of one of the authors the lack of adequate information in the literature regarding the most suitable heat treatments for production of the best combinations of strength and ductility for one per cent carbon steel. While considerable data are available relating to tensile properties of high carbon alloys, it was not possible to make satisfactory comparisons between the results reported by various investigators as to the effectiveness of different treatments for the purpose in view, due to the differences in chemical composition, size of specimens treated and other factors.

Because of the varied applications of slightly supersaturated carbon steels, including tools, dies, bearings and springs, tests were made to correlate properties and structure and to determine the magnitude of the effects observed with varying time-temperature relations in certain heat treating operations. At the same time treatments resulting in the best tensile and impact properties were sought.

Among the tests previously reported the following are considered of more particular interest in the treatment of one per cent carbon steel or deal with variables studied by the authors.

Sargent[1] found greatly increased strength with increase in annealing temperatures above the critical range and a maximum when cooled from 1025 degrees Cent. (1877 degrees Fahr.) which was decreased about 38 per cent when the temperature was raised to 1150 degrees Cent. (2102 degrees Fahr.). Maximum ductility was obtained in slow cooling from the upper end of the critical range, while temperatures even moderately above this reduced the elongation and reduction of area to very low values. The accompanying microstructural changes were marked and it was found that after annealing at 915 degrees Cent. (1670 degrees Fahr.), the cementite surrounding grains of pearlite had all left the boundaries and "gone toward binding groups of pearlite crystals into larger compound crystals".

Campbell[2] also studied the annealing of one per cent carbon steel and found that maximum strength was produced after slow cooling from 905 degrees Cent. (1661 degrees Fahr.) while the highest ductility and lowest strength was obtained when using 760 degrees Cent. (1400 degrees Fahr.) which is slightly above or at the end of the Ac_1 transformation. In general the inflections in curves for strength and elastic limit were accompanied by the reverse inflections in curves for elongation and reduction of area increases in one set being obtained at loss of the other.

Both Sargent's and Campbell's results are shown graphically in Fig. 1 while in Table I are given results of tests included in the Sixth Report to the Alloys Research committee[3] for steel containing 0.95 per cent car-

[1] George W. Sargent, "A Study of the Effect of Heat Treatment on Crucible Steel Containing One Per Cent Carbon." Trans. A. I. M. E., 1901, p. 303.

[2] William Campbell, "On the Heat Treatment of Some High Carbon Steels." Proc. Amer. Soc. Test. Mats., 1906, p. 211.

[3] Sir W. Roberts—Austen and W. Gowland, Sixth Report to the Alloys Research Committee, "On the Heat Treatment of Steel." Proc. Inst. Mech. Eng., 1904, Vol. 1, p. 7.

A paper presented by title at the Indianapolis Convention. The authors, H. J. French and W. George Johnson are physicist and assistant physicist respectively, Bureau of Standards, Washington, D. C. Published by permission of the director, Bureau of Standards.

bon. Maximum strength was obtained in slow cooling from 900 degrees Cent. (1652 degrees Fahr.) and the ductility gradually decreased with rise in temperature from 720 to 1100 degrees Cent. (1328 to 2012 degrees Fahr.). Soaking decreased the strength and in general resulted in an increase in elongation but at the same time produced a decrease in reduction of area.

From the preceding results it appears that slow cooling from temperatures just above Ac_1 gives maximum ductility and low strength. With rise in annealing temperature the ductility decreases rapidly and elongation and reduction of area in general remain at low values while the strength reaches a maximum in the range about 900 degrees Cent. (1652 degrees Fahr.).

Brinell[4] showed that the hardening capacity of carbon steels increased up to 0.45 per cent carbon when it became nearly constant with further increase to 0.90 per cent and thereafter decreased. The steel under consideration is, therefore, just above the range of maximum hardening capacity and, as is well known, is sensitive to thermal treatment, having slightly more carbon than required for saturation. After quenching in cold water from temperatures above the thermal transformation, it is hard and brittle while when more slowly cooled as in oil, high strength and somewhat greater ductility results. In either case the properties are changed to a marked degree by the quenching temperature whether

[4] Axel Wahlberg, "Brinell's Method of Determining Hardness and Other Properties of Iron and Steel." Jour. I. & S. Inst., 1901, Vol. 1, p. 243.

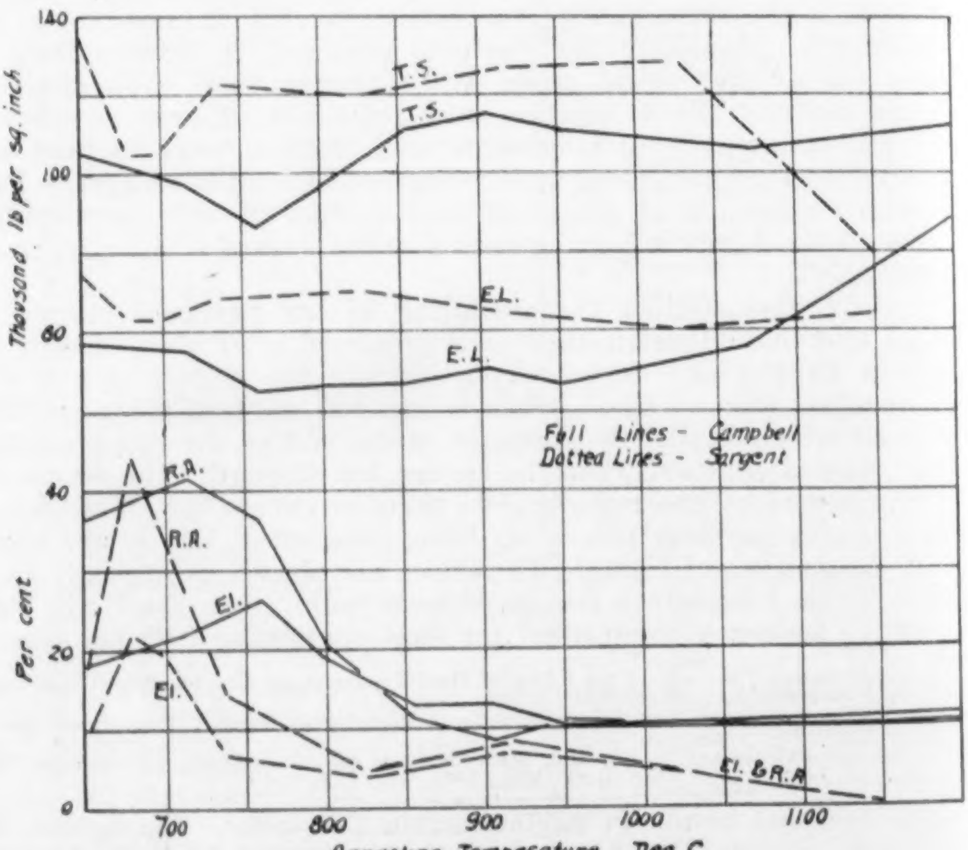

Fig. 1—Effect of different annealing temperatures on the tensile properties of 1 per cent carbon steel. Curves taken from William Campbell and G. W. Sargent

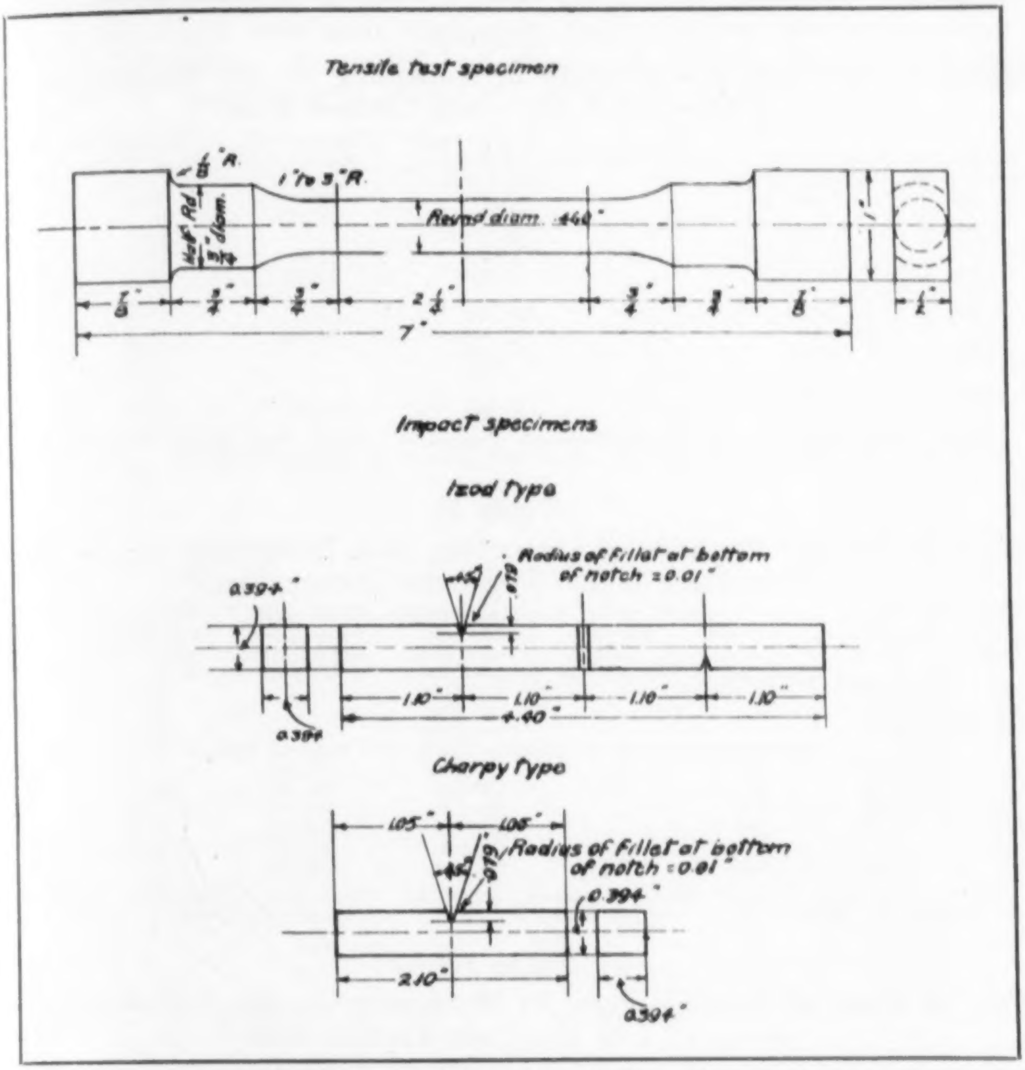

Fig. 2—Form and dimensions of test specimens used

subsequent tempering is at low or high temperatures or entirely omitted, as indicated by results reported by Roberts-Austen and Gowland[5] for an alloy containing 0.95 per cent carbon, which are reproduced in Table II. Based on their tests the authors conclude that the oil quenching temperature producing the best combination of strength, elastic limit and elongation is in the neighborhood of 900 degrees Cent. (1652 degrees Fahr.).

Hanemann[6] reported direct decrease in strength as the water hardening temperature increased from 750 to 1000 degrees Cent. (1382 to 1832 degrees Fahr.) for 1 per cent carbon steel not subsequently tempered whereas for an alloy containing 1.33 per cent carbon, the strength increased until the quenching temperature exceeded 900 degrees Cent. (1652 degrees Fahr.).

All that is considered necessary in the treatment of steel, as regards time at hardening temperature, is to maintain for the minimum period required for uniform heating throughout. The time actually required to

[5] See note 3.
[6] H. Hanemann, "Uber die Warmebehandlung der Stahle." Stahl and Eisen, 1911, 31, p. 1365.

Table I

Effect of Time and Temperature in Annealing on the Mechanical Properties of 0.95 Per Cent Carbon Steel*

Annealing temperature degrees Cent.	degrees Fahr.	Time at temperature hours	Breaking strength, pounds per square inch	Elastic limit, pounds per square inch	Elongation in 2 inches, per cent	Reduction of area, per cent
620	1148	½	118,400	76,600	15.0	27.0
		12	101,800	51,800	18.5	27.1
720	1328	½	88,000	.....	22.0	45.0
		12	75,500	31,600	23.5	35.4
800	1472	½	89,500	50,400	18.0	28.4
		12	......	.....	....	....
900	1652	½	114,500	.....	10.0	15.4
		12	107,000	80,800	11.9	11.0
1100	2012	½	111,300	.....	7.5	9.1
		12	......	.....	....	....
1200	2192	½	......	.....	....	....
		12	53,900	45,000	20.0	37.5

*From Sixth Report to the Alloys Research Committee. Proc. Inst. Mech. Eng., 1904, Vol. 1, p. 7. Pounds per square inch = tons per square inch given in original table x2240.

Table II

Effect of Various Methods of Quenching and Tempering on the Tensile Properties of 0.95 Per Cent Carbon Steel*

Quenched from degrees Cent.	degrees Fahr.	Tempered at degrees Cent.	degrees Fahr.	Breaking strength, pounds per square inch	Yield point, pounds per square inch	Elongation in 2 inches, per cent	Reduction of area, per cent
Quenched in Water at 20 Degrees Cent. (68 Degrees Fahr.)							
720	1328	...	...	125,500	.....	12.0	24.8
900	1652	...	...	48,400	.....	Nil	Nil
1200	2192	...	...	9,400	.....	Nil	Nil
Quenched in Oil at 80 Degrees Cent. (176 Degrees Fahr.)							
720	1328	...	...	117,100	89,500	13.0	19.8
720	1328	350	662	122,500	81,700	12.0	18.6
870	1598	350	...	229,500	149,400	7.0	17.0
1000	1832	350	...	211,000	152,700	5.5	14.8
800	1472	600	1112	103,000	80,000	12.0	12.9
900	1652	600	...	110,000	90,000	17.0	28.0

*From Sixth Report to the Alloys Research Committee. Proc. Inst. Mech. Eng., 1904, Vol. 1, p. 7. Pounds per square inch = tons per square inch given in original table x2240.

Table III

Effect of Time of Heating Prior to Hardening on the Mechanical Properties of 1.08 Per Cent Carbon Steel*

Time of heating at 800 degrees Cent. minutes	Maximum strength, pounds per square inch	Elastic limit, pounds per square inch	Elongation in 100 millimeters (3.94 inches) per cent	Reduction of area, per cent	Brinell hardness
2	91,500	78,300	10.5	17.2	600
20	121,000	121,000	10.5	17.2	571–652
60	125,000	122,000	10.5	17.2	875

*A. Portevin: "Influence du Temps de Chauffage avant la Trempe sur les Resultats de cette Operation." Rev. Met. (1916), 13, p. 9. Pounds per square inch = kilograms per square millimeter given in original tables x 1.422 x 103.

Table IV

Effect of Tempering on the Mechanical Properties of Hardened 1 Per Cent Carbon Steel*

Samples Quenched In Oil from 790 Degrees Cent. (1454 Degrees Fahr.)

Tempered at degrees Cent.	degrees Fahr.	Tensile strength, pounds per square inch	Yield point, pounds per square inch	Elongation in 2 inches, per cent	Reduction of area, per cent	Brinell hardness	Impact energy absorbed (Charpy foot-pounds per square inch
...	...	192,500	127,000	10.5	34.0	387	..
375	707	195,000	127,500	12.5	34.0	375	42
460	860	201,500	111,000	12.5	40.3	402	41
560	1040	168,500	104,500	14.5	30.7	321	54
650	1202	134,000	86,000	20.0	40.3	277	57
As rolled		152,000	86,000	9.5	13.3	302	27

*J. H. Nead: "The Effect of Carbon on the Physical Properties of Heat Treated Carbon Steel." Trans. A. I. M. E., 53 (1915), p. 218. "Charpy Results as Related to Carbon Content of Steel, Tests of Metals," etc., 1916, p. 109.

meet this condition is known to increase markedly with size and it is also known that with increased mass the temperature at which the steel will first harden, rises. Portevin[7] has shown that the effect of time of heating prior to quenching is marked and that a change from 2 to 60

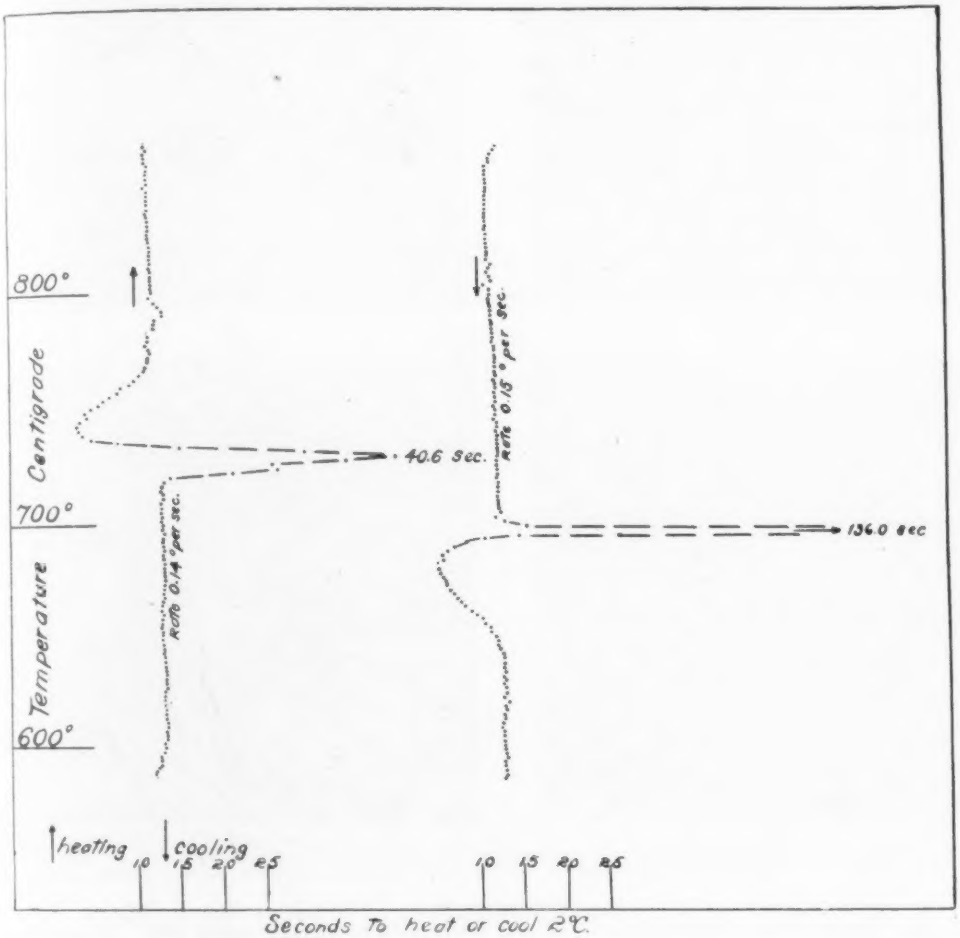

Fig. 3—Inverse rate heating and cooling curves of 1 per cent carbon steel. Data for Ac_1: Begins 716 degrees Cent.; maximum 727 degrees Cent.; ends 740 degrees Cent. Data for Ar_1: Begins 703 degrees Cent.; maximum 698 degrees Cent.; ends 680 degrees Cent.

minutes resulted in increased strength and hardness as shown in Table III.

The effects of tempering on the tensile and impact properties of hardened 1 per cent carbon steel have been studied by a number of investigators, including Rudeloff[8], Hanemann[9] and Roberts Austen and Gowland[10]. More recently J. H. Nead[11] determined the tensile and impact properties of such steel quenched in oil from the recommended annealing temperature range of the American Society for Testing Mate-

[7] A. Portevin, "Influence due temps de chauffage avant la trempe sur les resultats de cette operation." Rev. Met., 1916, 13, p. 9.

[8] M. Rudeloff, "Untersuchungen uber den Einfluss des Ausgluhens auf die physikalischen Eigenschaften von Eisen-und Stahdrahten." Stahl und Eisen, 1892, 12, p. 63.

[9] See note 6.

[10] See note 3.

[11] J. H. Nead, "The Effect of Carbon on the Physical Properties of Heat-Treated Carbon Steel." Trans. Amer. Inst. Min. Eng. 53, 1915, p. 218. "Charpy Results as Related to Carbon Content of Steel." Tests of Metals, etc., 1916, p. 109.

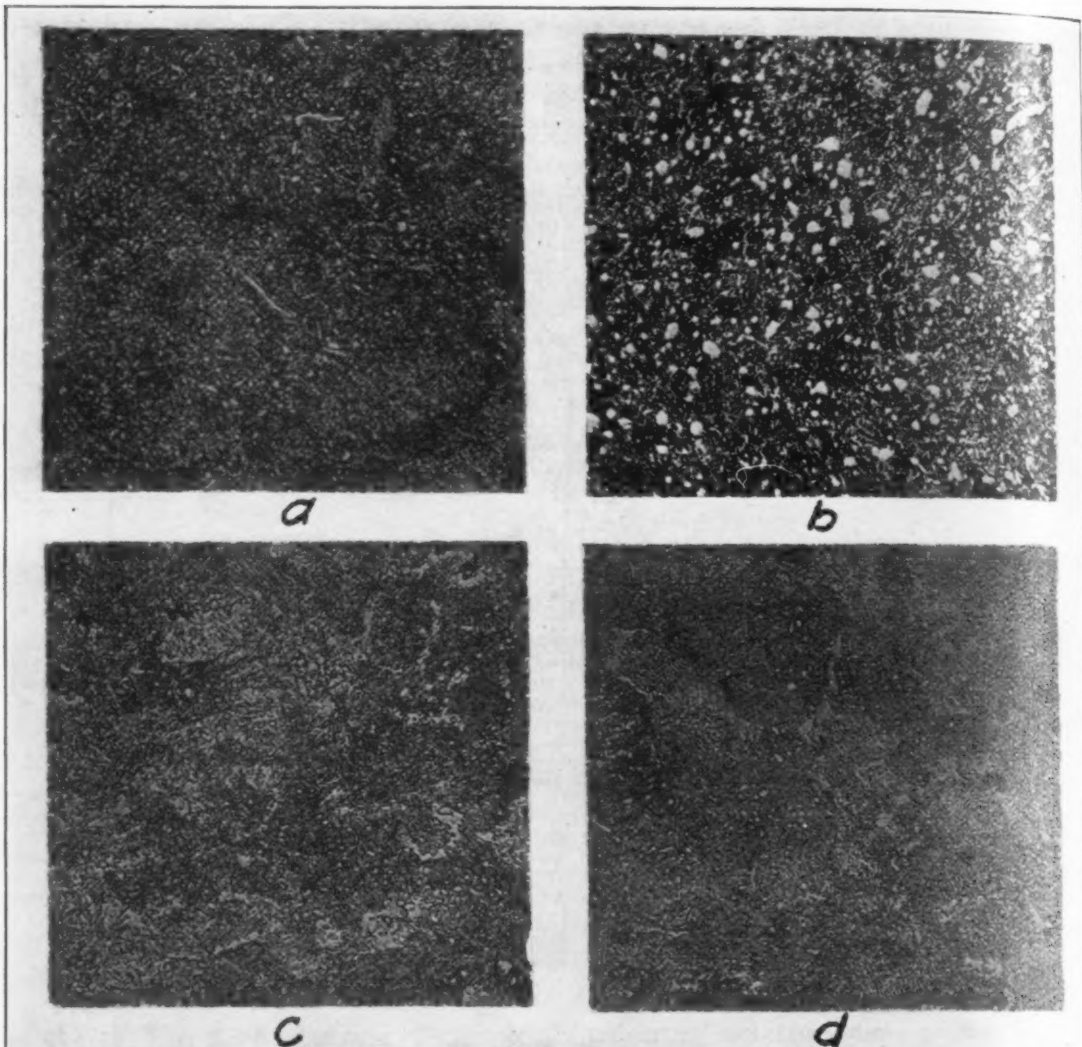

Fig. 4—Microstructure of 1 per cent carbon steel quenched from 788 degrees Cent. in different media and tempered at 538 degrees Cent. Etched with 2 per cent nitric acid in alcohol and X 500. *a* quenched in water. *b* quenched in oil. *c* quenched in molten lead at 538 degrees Cent. *d* quenched in molten sodium and potassium nitrates at 538 degrees Cent.

rials[12] when followed by tempering at various temperatures but the possibilities for production of high combinations of strength and ductility by varying hardening and tempering treatments have not been fully covered. It appears from Nead's results reproduced in Table IV that tempering has a relatively small effect in reducing the brittleness of the oil quenched steel and that tempering temperatures in the neighborhood of 500 degrees Cent. (932 degrees Fahr.) are required for a material increase in ductility or decrease in tensile strength. The cause of this is undoubtedly in incomplete hardening as specimens ½-inch or more in diameter will not be martensitic throughout after quenching in oil.

It is well recognized that a long time in tempering hardened steel at a given temperature is, within limits, equivalent to tempering for a short time at a higher temperature. Long time tempering at a given temperature increases the ductility and lowers the strength and hardness, but

[12] Year Book of the Amer. Soc. for Test. Materials, 1914, p. 201.

the magnitude of these effects, especially at the lower tempering temperatures, depends upon the thoroughness of the hardening. The fact that Hayward and Raymond[13] found relatively small effects on the tensile properties of 0.45 per cent carbon steel with increased time of tempering was probably due in part to incomplete hardening as pointed out in discussion of their results.

Mathews and Stagg[14] give detailed data relating to this subject and

[13] C. R. Hayward and S. S. Raymond, "Effect of Time on Reheating Hardened Carbon Steel Below the Critical Range." Trans. A. I. M. E., 1916, p. 517.

[14] J. A. Matthews and H. J. Stagg, "Factors in Hardening Tool Steel." Trans. Amer. Soc. Mech. Eng., 1914, p. 845.

Table V

Effect of Time in Tempering Hardened Steel*

Elastic limit, pounds per square inch	Maximum strength, pounds per square inch	Elongation, per cent	Reduction of area, per cent	Brinell hardness	Treatment
228,750	260,137	2.5	....	425	1550° F. oil, 800° F. 8 minutes
201,125	214,562	11.6	45.4	390	1550° F. oil, 800° F. 20 minutes
175,000	183,187	12.0	49.35	340	1550° F. oil, 800° F. 40 minutes

Results are average of four check tests after each treatment, carried out on ½-inch round tensile test bars.

*J. A. Matthews and H. J. Stagg: "Factors in Hardening Tool Steel," Trans. A. S. M. E., 1914, p. 845.

Table VI

Influence of Temperature on Time of Cooling in Quenching 1 Per Cent Carbon Steel*

Weight of specimen grams	Quenching temperature, degrees Cent.	Cooling time to 100 degrees Cent. in seconds
12.5	950	3.07
12.3	845	4.43
12.4	750	4.11
12.3	703	5.73
12.2	695	6.2

*C. Benedicks: "Experimental Researches on the Cooling Power of Liquids, on Quenching Velocities and on the Constituents Troostite and Austenite." Journ. I. & S. Inst., 1908, Vol. 2, p. 153.

Table VII

Effect of Time at 760 Degrees Cent. Prior to Oil Quenching on the Hardness of 1 Per Cent Carbon Steel

Heated at 760 degrees Cent. (1400 degrees Fahr..) for time specified and oil quenched	Brinell hardness
30 minutes	340
1 hour	351
5 hours	364

Table VIII

Comparison of Oil and Water Hardening of 1 Per Cent Carbon Steel for Production of Definite Strengths

Strength chosen, pounds per square inch	Method of hardening, degrees Cent.	Tempering required, degrees Cent.	Tempering required, degrees Fahr.	Proportional limit, pounds per square inch	Elastic ratio per cent	Elongation in 2 inches, per cent	Reduction of area, per cent	Hardness Brinell	Hardness Shore
200,000	843—oil	489	912	125,000	62.5	10.5	27.5	400	56
	788—oil	331	628	125,000	62.5	10.0	29.0	370	53
160,000	843—oil	611	1132	102,500	64.0	14.0	38.5	312	46
	788—oil	591	1096	101,500	63.5	15.5	42.2	302	44
	788—water	540	1004	136,500	85.3	12.0	32.0	342	54
135,000	843—oil	690	1274	88,000	65.1	19.5	48.0	260	41
	788—oil	661	1222	87,500	64.8	18.5	45.5	265	39
	788—water	608	1126	118,000	87.3	17.0	42.0	290	47
120,000	788—oil	696	1284	78,000	65.0	20.0	48.0	240	37
	788—water	648	1198	107,000	89.0	19.0	48.0	260	43

their values are reproduced in Table V. In part they state "......... time at the drawing temperature has a marked effect. The act of breaking down the martensite is progressive and not sharply defined. Both time and temperature have their effects."

Similarly other investigators have shown the importance of the time

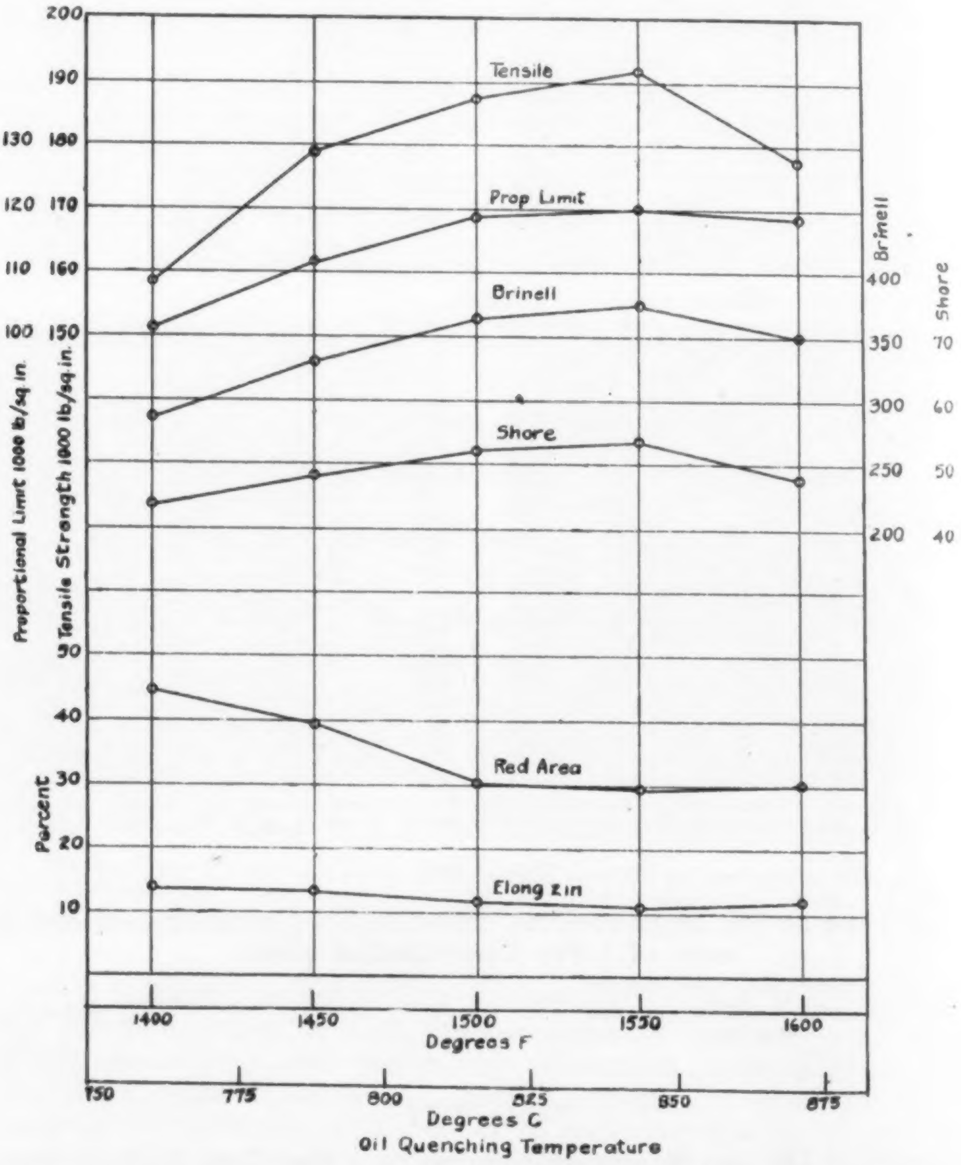

Fig. 5—Effect of varying oil quenching temperatures on mechanical properties of 1 per cent carbon steel subsequently tempered at 538 degrees Cent.

effect in tempering notably Barus and Stroubal[15] who used thermoelectric methods; Goerens[16] who studied variations in tensile, magnetic and other properties of low carbon steel; Portevin[17] who carried out hardness

[15] Barus and Stroubal, "On the Physical Characteristics of Iron Carburets." Bull. 14, U. S. Geol. Survey, 1885.

[16] P. Goerens, "Influence du Traitment thermique sur les proprietes de l'acier ecruit." Rev. Met. Memoires, 1913, 10, p. 1337.

[17] A. Portevin, "Influence du temps de chauffage avant le trempe sur les resultats de cette operation." Rev. Met., 1916, 13, p. 9.

tests; and microscopic examination, conducted by Rudeloff[18] and Hanemann[19]

The steel tested was part of a lot of 1-inch hot rolled bars of varying carbon contents supplied by the Carnegie Steel Co., Pittsburgh, and of the following chemical composition:

	Per Cent
Carbon	1.04
Manganese	0.17
Phosphorus	0.017
Sulphur	0.019
Silicon	0.14

After cutting to the desired lengths for tensile and impact specimens, the steel was normalized by heating to 815 degrees Cent. (1500 degrees Fahr.) for 30 minutes and cooling in still air, thereafter showing the following tensile properties and hardness:

Tensile strength, pounds per square inch	129,900
Proportional limit, pounds per square in	55,000
Elongation in 2 inches, per cent	14.0
Reduction of area, per cent	22.3
Brinell hardness	217
Shore hardness	32

Test samples were machined to slightly larger than the required size, approximately one-half round in reduced section, subjected to various heat treatments and finally ground wet to the form and dimensions shown in Fig. 2. Tensile tests were made with a 50,000-pound testing machine and a strain gage was used in determination of the limit of proportionality, while hardness was obtained by both the Shore and Brinell methods, by means of a recording scleroscope and an American Brinell hardness testing machine, the latter under standard conditions of 3000 kilogram load and 10 millimeter ball. Impact specimens of both Izod and Charpy types were tested in American made Izod and Charpy machines. Prior to subjecting the steel to heat treatment the thermal transformations were determined in a manner already described by Scott and Freeman[20]. The heating and cooling curves so obtained are shown in Fig. 3.

In order to throw further light on the effect of several methods of hardening 1 per cent carbon steel when followed by high tempering such as would possibly bring it into suitable condition for structural purposes, samples were quenched in water, oil, molten lead and a hot salt mixture consisting of 2 parts by weight of potassium nitrate and 3 parts sodium nitrate. The details of these treatments and test results are given in Table IX and it is evident that the surface of the treated metal is an important and determining factor in the tensile properties obtained. Removal of surface irregularities resulting from scaling in treatment including a large part or all of the decarburized surface results in better combinations of strength and ductility but the steel is brittle, as shown by the low impact values, regardless of the quenching method employed. In general, the most marked effect of grinding after treatment is found in values of reduction of area, which greatly increase.

It appears that the highest strength and ductility are obtained by cooling in oil but a much higher elastic ratio results from water quenching. It does not necessarily follow, however, that the results reported

[18] See note 8.

[19] See Note 6.

[20] H. Scott and J. R. Freeman Jr., "Use of a Modified Rosenhain Furnace for Thermal Analysis.' Bureau of Standards Scientific Paper 348, Oct. 24, 1919.

for any quenching method are the best which may be produced, for it is possible that better combinations of strength and ductility may be obtained when using higher quenching temperatures than 788 degrees Cent. (1450 degrees Fahr.) as is true when cooling in molten lead as shown in Table IX.

The structures of this steel after application of these different treatments are shown in Fig. 4 and after quenching in water or oil followed by tempering at 538 degrees Cent. (1000 degrees Fahr.) the steel is sorbitic. When quenched in molten lead or salt the steel consists of sorbitic pearlite but the transformation appears to have progressed somewhat further to pearlite in the case of the lead quenching.

The effect of different oil quenching temperatures on the properties and structure of steel subsequently tempered at 532 degrees Cent. (1000 degrees Fahr.) is marked as shown in Table XI and Figs. 5 and 6. With a rise in temperature to 843 degrees Cent. (1550 degrees Fahr.) strength and limit of proportionality increase and elongation and reduction of area decrease. With further rise in quenching temperature, the strength factors decrease with practically no change in ductility but in all cases the resistance to impact is low.

Benedicks[21] has shown that an increase in temperature results in more rapid cooling, for steel of constant mass and that the metal passes more rapidly through the transformations. His results for an alloy containing one per cent carbon are reproduced in part in Table VI.

It is quite evident, therefore, that a hardening of the matrix of the steel under investigation should result with rise in quenching temperatures and more carbide should be held in solution. In this case, however, there is an added factor contributing to the increased hardness and strength shown in Fig. 5 in the retention of the excess cementite when quenching from above its solution temperature range. The rate of cooling in oil when the steel is heated to 843 degrees Cent. (1550 degrees Fahr.) is not sufficiently rapid to retain all this carbide in solution but an increase to 871 degrees Cent. (1600 degrees Fahr.) increases the cooling rate through the transformations enough to cause retention of the few remaining globules found after the first mentioned treatment. These structures as well as those obtained on using lower quenching temperatures are shown in Fig. 6 and because of the tempering at 538 degrees Cent. (1000 degrees Fahr.), the ground mass is sorbitic. There is free cementite present in good proportion until quenching temperatures above 816 degrees Cent. (1500 degrees Fahr.) are used, while the condition of maximum strength obtained in the sample quenched from slightly above the Acm transformation, is coincident with the minimum proportion of free carbide. Undoubtedly the cementite is first wholly retained in quenching from a temperature somewhat below 871 degrees Cent. (1600 degrees Fahr.) where the first disappearance has been noted and possibly this condition would be coincident with higher strength than shown in Fig. 5. However, it is acknowledged that each increase in temperature is accompanied by increased grain size. This effect opposes whatever beneficial results might be obtained by total retention of the cementite and will finally induce greater brittleness and lowered tensile strength and that this has happened in the range under consideration is shown by

[21] C. Benedicks, "Experimental Researches on the Cooling Power of Liquids, on Quenching Velocities and on the Constituents Troostite and Austenite." Jour. I. & S. Inst., 1908, Vol. 2, p. 153.

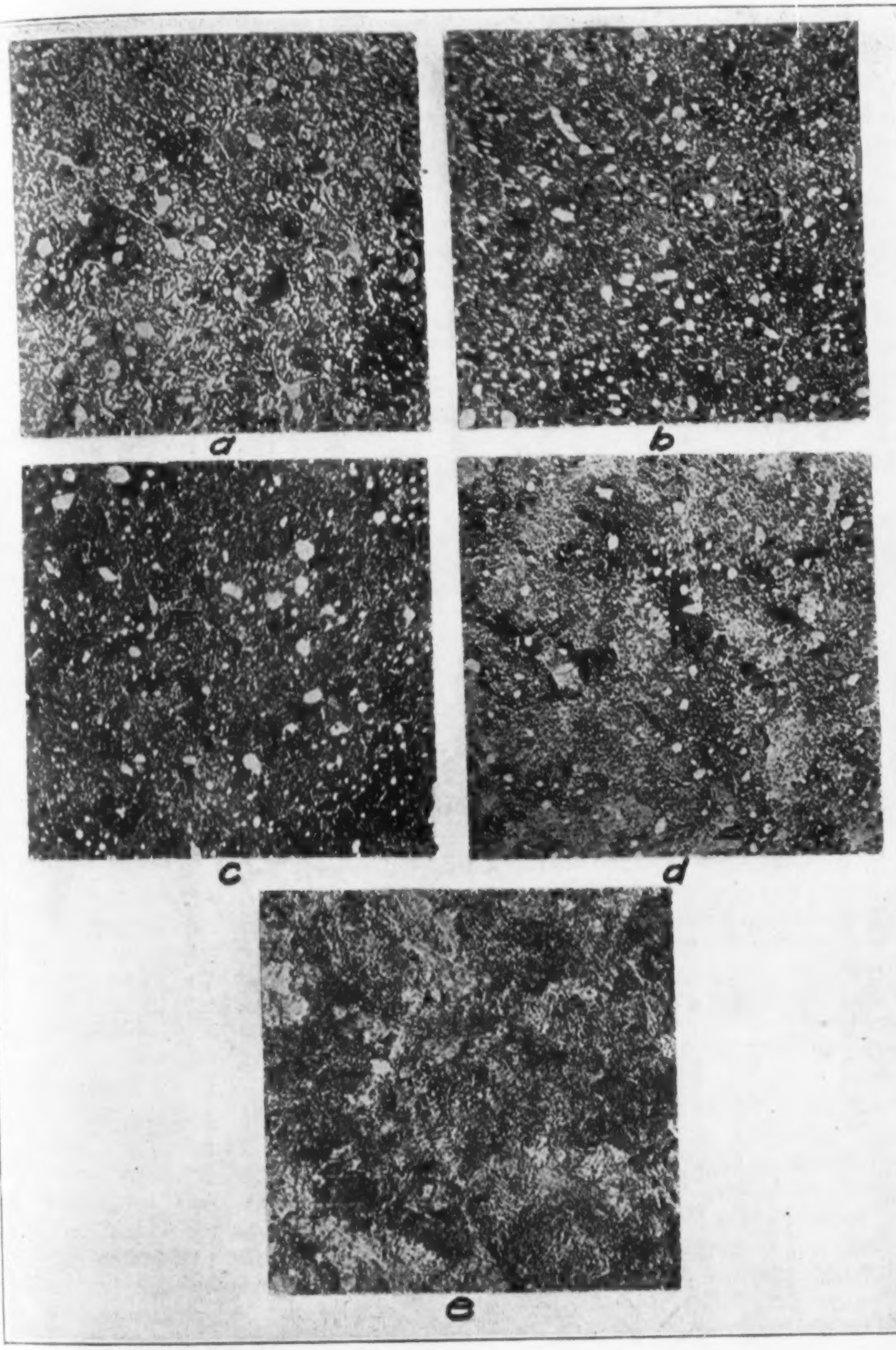

Fig. 6—Microstructure of 1 per cent carbon steel, oil quenched from various temperatures and subsequently tempered at 538 degrees Cent. Etched with 2 per cent nitric acid in alcohol and X 500. *a* quenched from 760 degrees Cent. (1400 degrees Fahr.). *b* quenched from 788 degrees Cent. (1450 degrees Fahr.). *c* quenchd from 816 degrees Cent. (1500 degrees Fahr.). *d* quenched from 843 degrees Cent. (1550 degrees Fahr.). *e* quenched from 871 degrees Cent. (1600 degrees Fahr.)

Table IX

Mechanical Properties of 1 Per Cent Carbon Steel Quenched from 788 or 843 Degrees Cent. in Different Media and Subsequently Tempered at 538 Degrees Cent.

Treatment	Sample No. *	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed, Foot Pounds Charpy Values	Charpy Average	Izod Values	Izod Average
788 degrees Cent. (1450 degrees Fahr) 30 minute water quench. Tempered 15 to 20 minutes, 538 degrees Cent. (1000 degrees Fahr.)	51 B	165,500	143,000	11.0	27.7	340	56				
	52 B	156,200	132,000	12.5	34.6	340	53	2.5–3.1–3.2	2.9	2.2–2.2–2.0	2.2
	49 A	114,400	98,900	14.0	23.1	262	42				
	50 A	116,200	101,400	15.0	26.1	255	43				
843 degrees Cent. (1550 degrees Fahr.) 30 minutes water quench. Tempered 15 to 20 minutes 538 degrees Cent. (1000 degrees Fahr.)	49 B	171,650	130,000	9.5	31.4	340	51				
	50 B	160,800	125,000	10.5	31.0	340	45				
	51 A	143,200	82,000	6.5	11.5	294	46				
	52 A	138,500	92,000	7.5	8.2	286	46				
788 degrees Cent. (1450 degrees Fahr.) 30 minute oil quench. Tempered 15 to 20 minutes 538 degrees Cent. (1000 degrees Fahr.)	3 B	188,250	110,500	....	....	340	48				
	4 B	169,000	113,000	13.0	39.3	318	48				
	13 A	157,500	92,500	11.0	16.5	321	48	3.0–3.5–2.3	2.9	2.0–2.0–3.0	2.3
	14 A	156,100	90,000	10.5	16.1	321	48				
788 degrees Cent. (1450 degrees Fahr.) 30 minute salt quench at 538 degrees Cent. (1000 degrees Fahr.) holding 15 minutes before cooling in oil.	43 B	133,700	90,500	14.5	35.0	294	42				
	44 B	147,000	80,500	14.5	36.0	289	40	3.9–3.6–3.4	3.8	4.2–3.4–3.8	3.8
	7 A	143,000	81,500	8.5	22.5	278	39				
	8 A	142,900	77,500	8.5	17.0	294	42				
788 degrees Cent. (1450 degrees Fahr.) 30 minute lead quench at 538 degrees Cent. (1000 degrees Fahr.), holding 15 minutes before cooling in oil. 843 degrees Cent. (1550 degrees Fahr.) 1 hour lead quench at 538 degrees Cent. (1000 degrees Fahr.), holding 30 minutes before cooling in oil.	47 B	151,800	84,000	15.0	37.4	255	37				
	48 B	148,200	81,000	14.5	36.3	278	37	3.2–3.5–3.0	3.2	3.1–3.0–3.3	3.1
	9 A	130,800	71,000	10.0	12.6	238	38				
	10 A	131,200	68,500	9.5	12.4	228	31				
	25 A	136,700	70,000	12.0	23.2	248	33				
	26 A	139,200	72,500	10.0	15.2	278	36				

*Samples marked B were ground wet after treatment and before testing; those marked A were tested without grinding after heat treatment.

Table X

Effect of Time Slightly Below Ac_1 on the Mechanical Properties of 1 Per Cent Carbon Steel Previously Oil Quenched from 843 Degrees Cent.

Specimen No.	Heated at 704 degrees Cent. (1300 degrees Fahr.) for time specified and then oil quenched. Hours	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed Foot Pound Charpy	Impact Energy Absorbed Foot Pound Izod
23 B	½	126,200	86,000	18.8	46.7	260	40	3.3–3.0	3.0–2.8–3.0
24 B		140,200	....	17.0	40.2	248	40		4.5–5.5–6.0
Average		133,200	86,000	17.9	43.4	254	40	3.2	4.1
34 B	1	121,500	79,000	....	....	241	39		
64 B		113,200	81,500	19.0	48.4	235	39		
Average		117,350	80,250	...	....	238	39		
35 B	5	86,100	54,500	33.0	61.3	156	32	2.8–8.4–2.5	2.6–2.3–3.9
36 B		93,900	72,000	....	....	207	34		
Average		90,000	63,250	....	....	182	33	4.6	2.9

the sharp decrease in strength between samples quenched from 843 and 871 degrees Cent. (1550 and 1600 degrees Fahr.).

In order to further investigate the magnitude of the effects of "soaking" at various hardening temperatures, samples were held for different intervals at 760 degrees Cent. (1400 degrees Fahr.) and 843 degrees Cent.

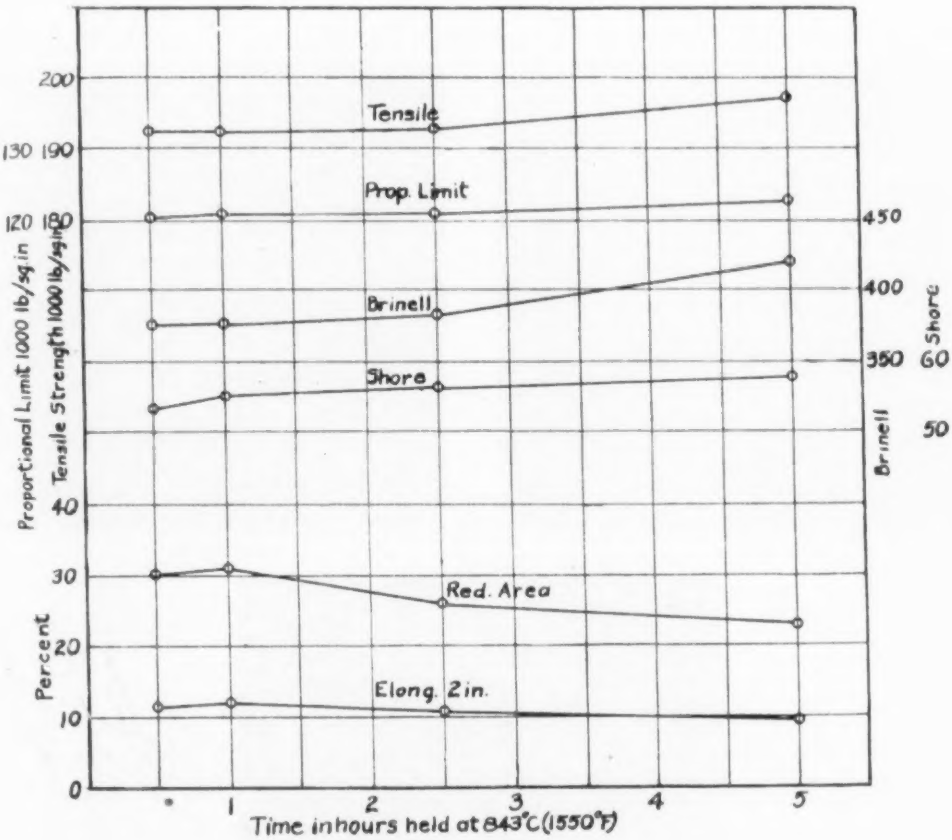

Fig. 7—Effect of time at 843 degrees Cent. on the mechanical properties of 1 per cent carbon steel subsequently oil quenched and tempered at 538 degrees Cent.

(1550 degrees Fahr.) prior to quenching in oil and tempering. The first temperature is just above or at the end of Ac_1 while the latter is slightly above the temperature range at which the excess carbide goes into solution.

The time over 30 minutes for which the steel is held at 843 degrees Cent. (1550 degrees Fahr.) when subsequently oil quenched and tempered at 538 degrees Cent. (1000 degrees Fahr.) has a relatively small effect on the tensile and impact properties, as shown in Fig. 7 and Table XII. A change from 30 minutes heating to 1 hour does not alter the strength appreciably but results in slightly increased ductility whereas with increase in time of soaking from 1 to 5 hours the hardness, tensile strength and proportional limit gradually increase with accompanying decrease in elongation and reduction of area. The steel is very brittle after all treatments and the variations in impact resistance are not such as to allow conclusions to be drawn.

The hardening temperature chosen is only slightly above the solution temperature of the excess carbide which, according to recent determina-

tion of Ishiwara[22] takes place at about 835 degrees Cent. (1535 degrees Fahr.) and that this reaction proceeds slowly is at once evident from examination of the structures shown in Fig. 8. Solution is incomplete at 30 to 45 minutes whereas in 2½ hours this change has progressed nearly to completion, coincident with a marked decrease in reduction of area in tensile test. In the sample heated for 5 hours that excess carbide is

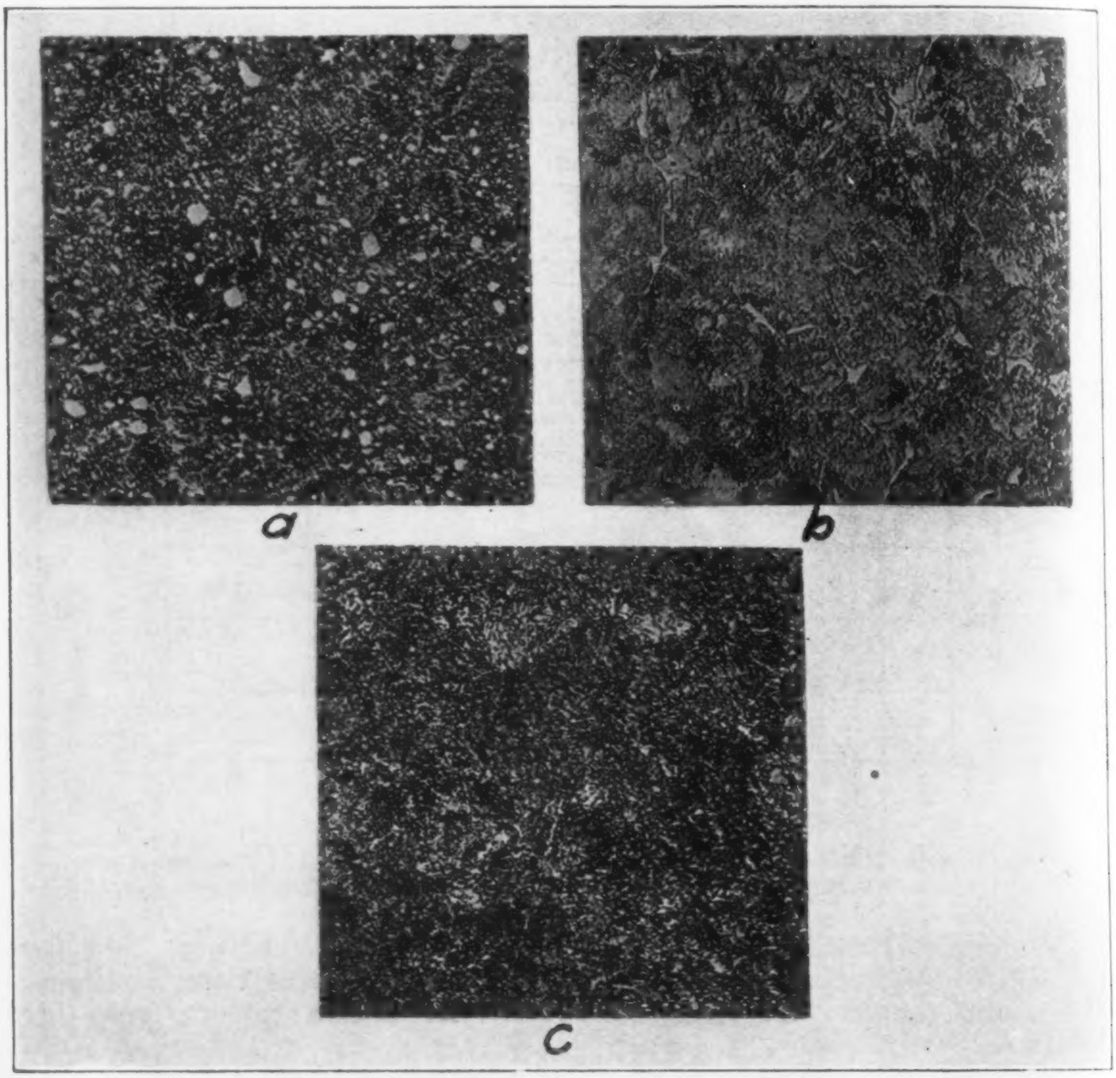

Fig. 8—Microstructure of 1 per cent carbon steel held at 843 degrees Cent. for various times and subsequently oil quenched and tempered at 538 degrees Cent. Etched with 2 per cent nitric acid in alcohol and X 500. *a* held 45 minutes. *b* held 2½ hours. *c* held 5 hours

wholly in solution which partly accounts for the increased hardness obtained.

When this steel is soaked at 760 degrees Cent. (1400 degrees Fahr.) which is slightly above the end of the Ac_1 transformation, oil quenched and subsequently tempered as in the preceding samples marked changes in properties result as illustrated in Fig. 9 and Table XIII. An increase in time at hardening temperature from 30 minutes to 2 hours results in in-

[22] Torajuro Ishiwara, "On the Magnetic Determinations of A_0, A_1, A_2, and A_3 Points in Steels Containing Up to 4.8 Per Cent Carbon." Science Reports of the Tohoku Imperial Univ., Vol. 9, No. 5, p. 401.

Table XI

Effect of Varying Oil Quenching Temperatures on the Mechanical Properties of 1 Per Cent Carbon Steel Subsequently Tempere d at 538 Degrees Cent.

Specimen No.	Heated to temperatures noted, held 30 minutes and quenched in oil.* Degrees Cent.	Degrees Fahr.	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per Cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed, Foot Pound Charpy	Izod
1 B	760	1400	158,000	101,000	13.5	44.3	288	43	2.2–2.5–3.0	2.3–2.2–2.5
60 B			....	....	....	....	...	..		
Average			....	....	....	....	...	..	2.6	2.3
3 B	788	1450	188,250	110,500	....	....	340	48	3.0–3.5–2.3	2.0–2.0–3.0
4 B			169,000	113,000	13.0	39.3	318	48	3.0–3.5–2.3	2.0–2.0–3.0
Average			178,600	111,750	13.0	39.3	329	48	2.9	2.3
5 B	816	1500	193,600	122,000	10.0	29.2	364	54	3.1–3.3–3.6	
6 B			181,600	116,000	12.5	31.0	364	50		
Average			187,600	119,000	11.2	30.1	364	52	3.3	
7 B	843	1550	199,000	121,000	10.5	29.5	364	53	3.1–3.3–3.1	3.1–3.2–3.1
8 B			185,000	119,000	11.5	29.5	387	54		
Average			192,000	120,000	11.0	29.5	376	54	3.2	3.1
9 B	871	1600	177,900	118,000	11.5	30.3	345	46	3.2–3.9–3.9	3.1–2.8–3.1
10 B			177,100	119,000	12.5	29.8	356	50		
Average			177,500	118,500	12.0	30.0	350	48	3.7	3.0

*All samples subsequently tempered at 538 Degrees Cent. (1000 degrees Fahr.) for 20 minutes and cooled in oil.

Table XII

Effect of Time at 843 Degrees Cent. on the Mechanical Properties of 1 Per Cent Carbon Steel Subsequently Tempered at 538 degrees Cent.

Specimen No.	Heated to 843 degrees Cent. (1550 degrees Fahr.) for time noted and oil quenched. Tempered 20 minutes at 538 degrees Cent. (1000 degrees Fahr.) hours	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed Foot Pound Charpy	Izod
7 B	½	199,000	121,000	10.5	29.5	364	53	3.1–3.3–3.1	3.1–3.2–3.1
8 B		185,000	119,000	11.5	29.5	387	53		
Average		192,000	120,000	11.0	29.5	376	53	3.2	3.1
27 B	1	202,100	128,000	10.5	27.7	387	56		
28 B		181,800	113,000	12.5	34.4	364	54		
Average		191,950	120,500	11.5	31.0	376	55		
65 B	2½	192,350	121,000	11.0	26.3	376	55		
29 B		193,400	120,500	9.5	26.6	387	57		
Average		192,875	120,750	10.2	26.4	382	56		
31 B	5	207,900	129,500	8.5	19.5	477	56	3.2–3.2–4.0	3.1–3.1–3.0
32 B		187,000	116,000	10.5	27.0	364	59		
Average		197,450	122,750	9.5	23.2	421	58	3.5	3.1

Table XIII

Effect of Time at 760 Degrees Cent. on the Mechanical Properties of 1 Per Cent Carbon Steel Subsequently Oil Quenched and Tempered at 538 Degrees Cent.

Specimen No.	Time at Oil Quenching Temperature of 760 Degrees Cent. (1400 degrees Fahr.) Hours	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed Foot Pound Charpy	Impact Energy Absorbed Foot Pound Izod
25 B	½	186,800	117,500	11.0	38.1	321	45	3.1-2.9-3.0	2.8-2.7-3.0
26 B		170,000	108,000	11.5	41.6	304	40		
Average		175,400	112,750	11.2	39.8	313	43	3.0	2.8
37 B	1								
38 B		183,250	117,000	10.5	36.8	358	53		
Average									
39 B	2	192,800	119,000	9.5	25.2	382	56		
40 B		198,700	120,000	10.5	29.3	387	60		
Average		195,750	119,500	10.0	27.2	385	58		
41 B	5	192,500	118,500	8.0	20.9	376	58		
42 B		192,000	120,000	8.5	24.0	398	58		
Aaerage		192,250	119,250	8.2	22.4	387	58		

Table XIV

Effect of Tempering on the Mechanical Properties of 1 Per Cent Carbon Steel First Quenched in Water from 788 Degrees Cent.

Specimen No.	Held 20 minutes at tempering temperature indicated and air cooled. Degrees Cent.	Degrees Fahr.	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed, Foot Pound Charpy	Impact Energy Absorbed, Foot Pound Izod
51 B	538	1000	165,500	143,000	11.0	27.7	340	56	2.5-3.1-3.2	2.2-2.2-2.0
52 B			156,200	132,000	12.5	34.6	340	53		
Average			160,850	137,500	11.8	31.2	340	54	2.9	2.1
53 B	649	1200	....	106,500	17.0	47.4	255	43		
54 B			118,800	106,000	22.0	48.6	255	43	3.2-2.6	2.3-2.0-2.1
Average			....	106,250	19.5	48.0	255	43	2.9	2.1
55 B	704	1300	108,400	91,000	....	....	223	34	5.7-10.7-8.5	11.0-5.5-7.7
56 B			108,700	95,000	25.0	52.9	220	34	3.0-2.9-2.8	2.0-2.4-2.3
Average			108,650	93,000	....	....	222	34	5.6	5.2
67 B	760	1400	124,400	68,000	16.5	37.0	255	34	3.2-2.3-2.7	2.6-2.4-2.2
68 B			115,800	67,500	18.5	44.6	269	39		
Average			120,100	67,750	17.5	40.8	262	36	2.7	2.4

creased hardness, strength and limit of proportionality with decrease in ductility, particularly as measured by reduction of area. Between 2 and 5 hours the changes in properties are negligible, there being evident principally a small decrease in strength.

In Fig. 10 are shown the structures of the steel under the treatments used and with increase in time at temperature there is more free cemen-

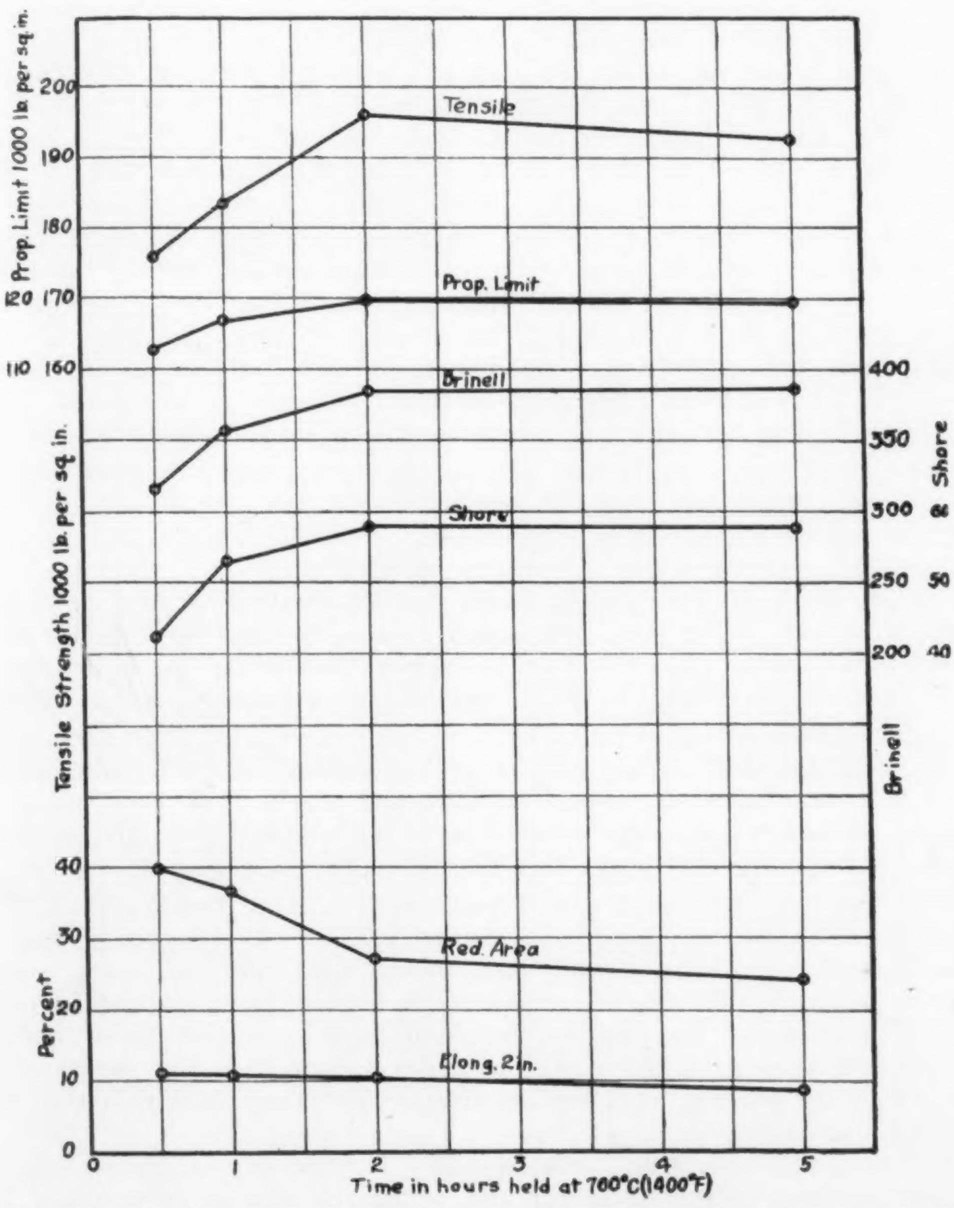

Fig. 9—Effect of time at 760 degrees Cent. on the mechanical properties of 1 per cent carbon steel subsequently oil quenched and tempered at 538 degrees Cent.

tite and the small globules of this constituent appear to combine to form larger ones as shown in Figs. 10*e* and 10*f*. While these changes are to be noted, a marked difference in the etching qualities of the ground mass is observed indicating that the structural changes accompanying the variations in tensile properties are partly due to changes in the condition of

the matrix. Specimens heated for various intervals and oil quenched without subsequent tempering were examined under the microscope and found to consist of troosto-sorbite and it appeared that the proportion of troostite was greater the longer the soaking.

When supplemented by Brinell hardness tests, the results of which are given in Table VII, it is evident that the effect of increasing the duration of heating for hardening results in a noticeable increase in hardness as does an increase in temperature.

To supplement available information and to correlate the tensile and impact properties of one heat of steel tempered at different temperatures after hardening in different ways, samples were tempered between 316 and 704 degrees Cent. (600 and 1300 degrees Fahr.) after quenching in oil or in water from just above or at the end of Ac_1 and in oil from a temperature slightly above the Acm transformation.

The results obtained in tests of steel quenched in water from 788 degrees Cent. (1450 degrees Fahr.) followed by tempering between 538 and 704 degrees Cent. (1000 and 1300 degrees Fahr.) are given in Fig. 11 and Table XIV and it is noted that the most rapid decrease in strength occurs when the tempering temperature is raised from about 538 to 649 degrees Cent. (1000 to 1200 degrees Fahr.) while at the same time the elongation is almost doubled and reduction of area materially increased.

The mechanical properties-tempering temperature curves shown in Fig. 12 are based on results given in Table XV for steel quenched in oil from 788 or 843 degrees Cent. (1450 or 1550 degrees Fahr.) and are of the same general type. Samples quenched at the highest temperature show the highest strength with lowest elongation and reduction of area throughout than those quenched from 788 degrees Cent. (1450 degrees Fahr.), or in other words, a higher tempering temperature is required when using the highest quenching temperature to produce a given strength.

By interpolation of the graphs giving variations in tensile properties of the tempered steel hardened in different ways, it is possible to compare the various treatments applied in order to produce a given strength and the results obtained from this approximation are given in Table VIII.

For the production of given strength by heat treatment a slightly higher tempering temperature is required after oil quenching from just above the Ac_1 transformation than when the steel is water quenched from the same temperature. Likewise a higher temperature is required when oil quenching from above the Acm transformation than when similarly cooled from just above Ac_1 in order to produce the same strength. In general this difference is less as the temperature at which the steel is tempered increases.

Water quenched steel subsequently tempered to show the same strength as that quenched in oil and tempered has a very much higher proportional limit than the latter and also greater hardness as measured by the Brinell and Shore methods. As the tempering temperature approaches the lower critical range these differences at first decrease and then slightly increase. While the difference between the hardness of water and oil quenched steels is well known, it is interesting to note the magnitude of this difference for the steel under consideration and the fact that it is maintained over a wide range of tempering.

In view of the slight difference in tensile properties between the

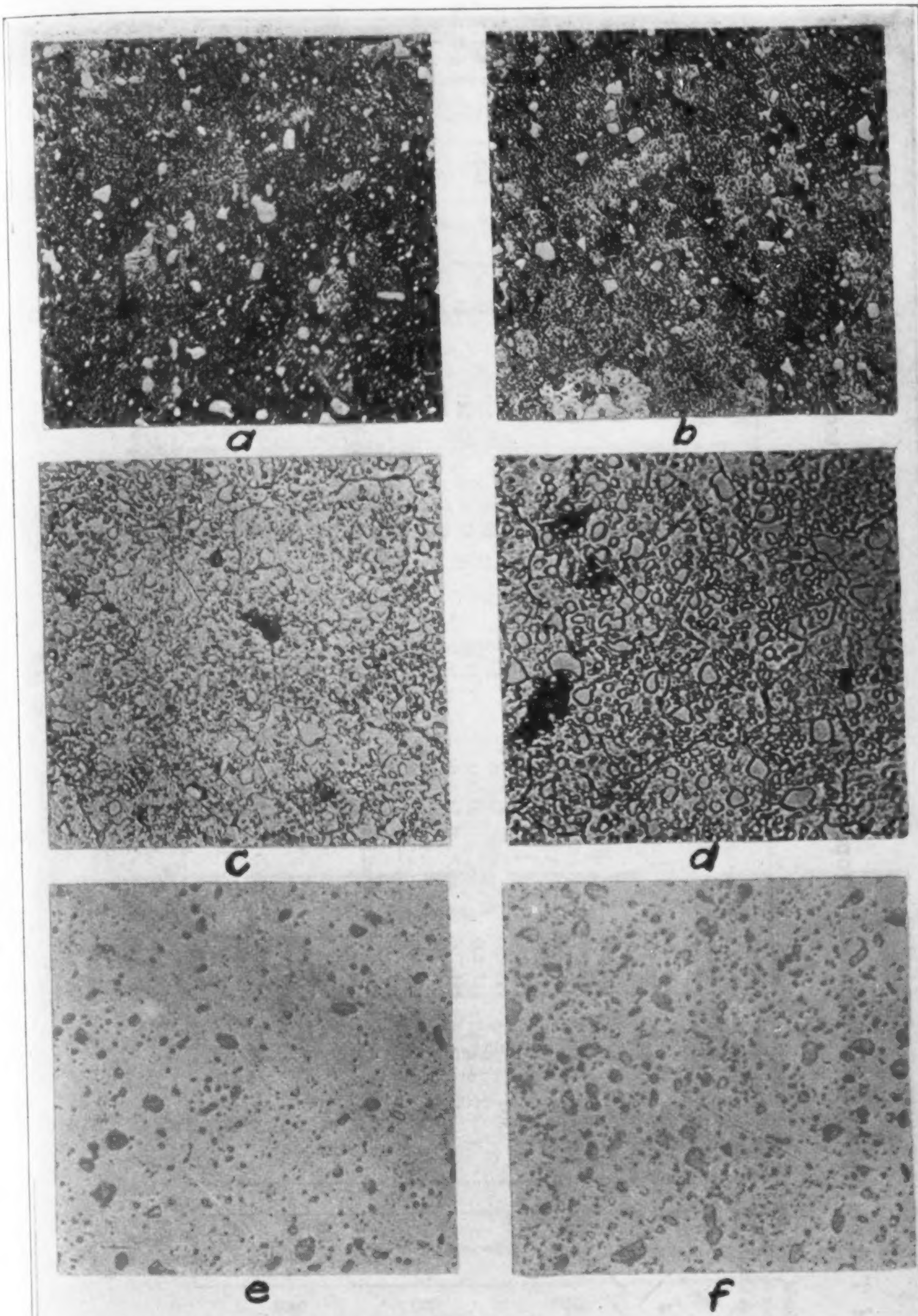

Fig. 10—Microstructure of 1 per cent carbon steel held at 760 degrees Cent. for various times and subsequently oil quenched and tempered at 538 degrees Cent. X 500. *a* held 30 minutes. *b* held 1 hour. *c* held 2 hours. *d* held 5 hours. *e* held 30 minutes. *f* held 5 hours. *a*, *b*, *c* and *d* etched in 2 per cent nitric acid in alcohol. *e* and *f* etched in boiling sodium picrate

Table XV

Effect of Tempering on the Mechanical Properties of 1 Per Cent Carbon Steel First Oil Quenched from 788 or 843 Degrees Cent.

Specimen No.	Held 30 minutes at tempering temperature indicated and oil quenched Degrees Cent.	Degrees Fahr.	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Shore	Impact Energy Absorbed Foot Pound Charpy	Izod
Steel heated for 30 minutes at 788 degrees Cent. (1450 degrees Fahr.) and oil quenched										
11 B	316	600	197,000	122,000	8.0	24.8	364	52	2.2-3.1-3.3	2.7-2.1-3.3
12 B			206,000	130,000	9.5	32.0	386	56	4.8-7.5-4.8	
Average			201,500	126,000	8.8	28.4	375	54	4.3	2.7
3 B	538	1000	188,250	110,500	....	....	340	48	3.0-3.5-2.3	2.0-2.0-3.0
4 B			169,000	113,000	13.0	39.3	318	48	3.9-3.9-4.8	
Average			178,600	111,750	....	....	329	48	3.5	2.3
13 B	649	1200	140,700	93,000	18.0	45.3	278	41	3.0-3.1-3.0	2.3-2.0-2.4
14 B			141,800	91,500	...	....	277	41	3.9-4.4-3.9	
Average			141,250	92,250	....	....	278	41	3.5	2.2
59 B	704	1300	115,800	72,500	20.0	49.8	235	36	2.8-2.1-2.2	3.5-3.7-4.0
16 B			117,800	82,000	21.0	47.6	241	36		2.6-2.1-2.1
Average			116,800	77,250	20.5	48.7	238	36	.0	3.0
17 B	760	1400	171,700	108,000	12.0	40.4	302	42		
18 B			171,600	110,000	11.5	42.3	286	40		
Average			171,650	109,000	11.7	41.3	294	41		
Steel heated for 30 minutes at 843 degrees Cent. (1550 degrees Fahr.) and oil quenched										
61 B	316	600	228,000	145,000	8.0	20.3	512	66	3.1-3.2-3.0	4.0-2.7-3.8
62 B			228,200	147,000	8.0	20.3	470	64	8.0-2.2	
Average			228,100	146,000	8.0	20.3	491	65	3.9	3.5
7 B	538	1000	199,000	121,000	10.5	29.5	364	53	3.1-3.3-3.1	3.1-3.2-3.1
8 B			185,000	119,000	11.5	29.5	387	54		
Average			192,000	120,000	11.0	29.5	376	54	3.2	3.1
22 B	649	1200	....	90,500	17.5	45.6	277	42	3.9-4.8-4.8	3.5-3.5-3.5
63 B			144,700	98,500	15.0	41.0	290	42		
Average			144,700	94,500	16.2	43.3	284	42	4.5	3.5
23 B	704	1300	125,200	86,000	18.8	46.7	260	40	3.3-3.0	3.0-2.8-3.0
24 B			140,200	....	17.0	40.2	248	40	9.6-6.6-4.8	4.5-5.5-6.0
Average			132,700	86,000	17.9	43.4	254	40	5.5	4.1
25 B	760	1400	186,800	117,500	11.0	38.1	319	45	3.1-2.9-3.0	2.8-2.7-3.0
26 B			170,000	108,000	11.5	41.6	332	40		
Average			178,400	112,750	11.2	39.8	326	43	3.0	2.8

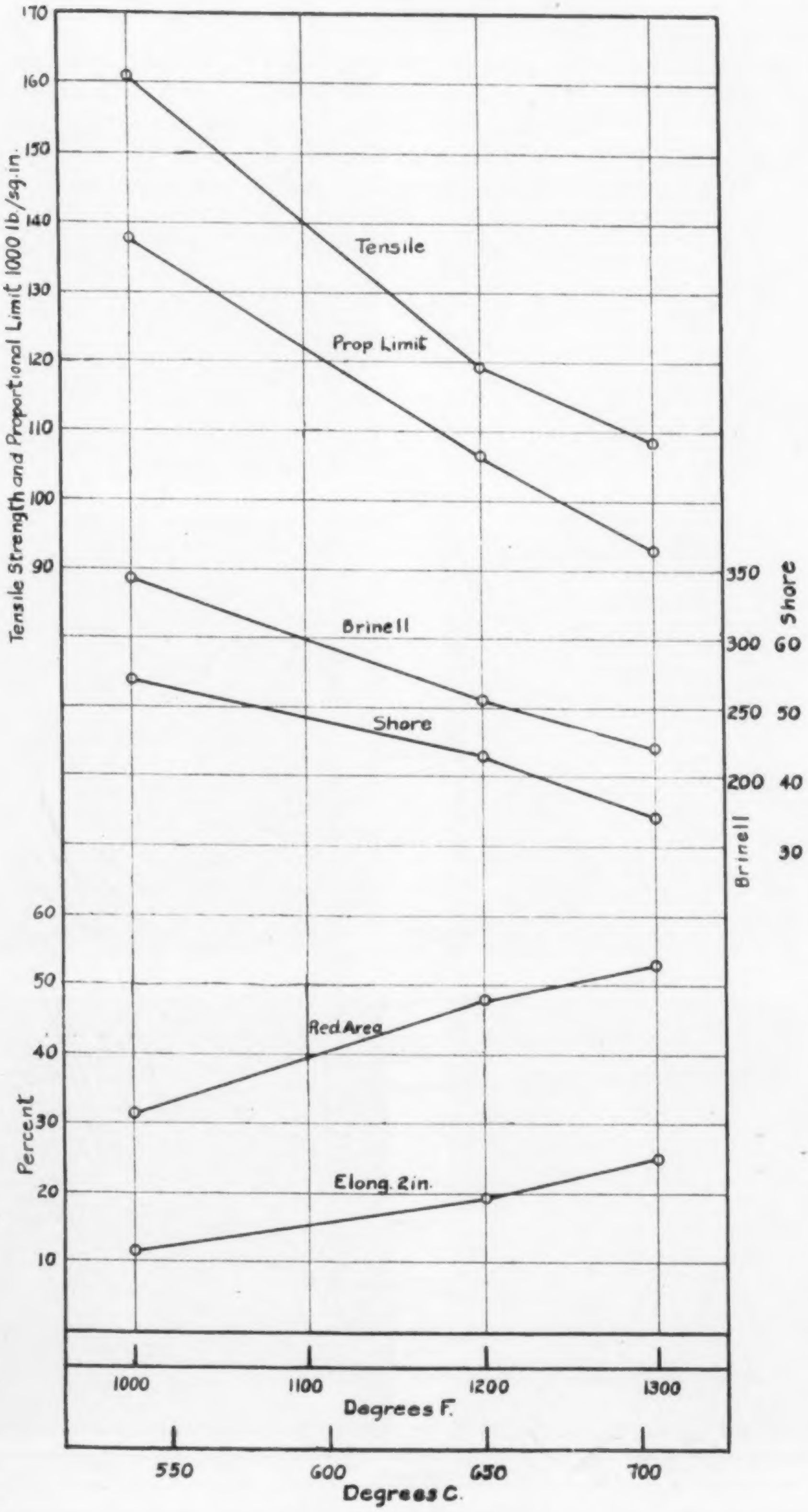

Fig. 11—Effect of tempering on the mechanical properties of 1 per cent carbon steel first quenched in water from 788 degrees Cent.

steel quenched in oil from 788 degrees Cent. (1450 degrees Fahr.) and that from 843 degrees Cent. (1550 degrees Fahr.) the lower temperature is recommended. If the excess carbide exists in plate form due to a previous high heating it may be refined readily by normalizing. A preliminary quench from above Acm, however, appears preferable. Water hardening is the best method, for the production of strengths in the neighborhood of 120,000 pounds square inch requiring a tempering of about 649 to 710 degrees Cent. (1200 to 1300 degrees Fahr.), providing always that the size and shape of the material is such as to allow the use of a drastic quenching medium.

The structures of samples subjected to the various tempering treat-

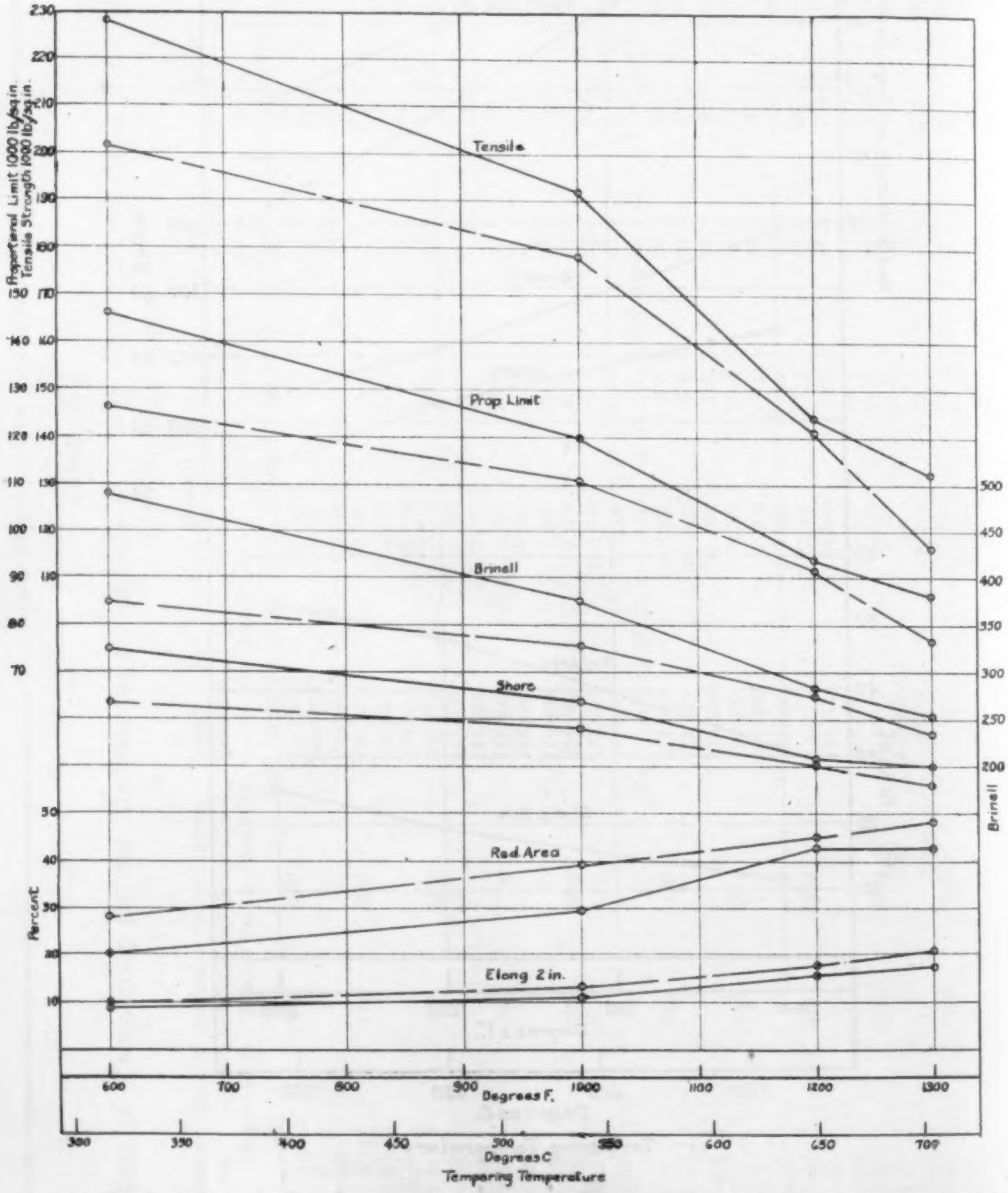

Fig. 12—Effect of tempering on the mechanical properties of 1 per cent carbon steel first oil quenched from either 788 or 843 degrees Cent.

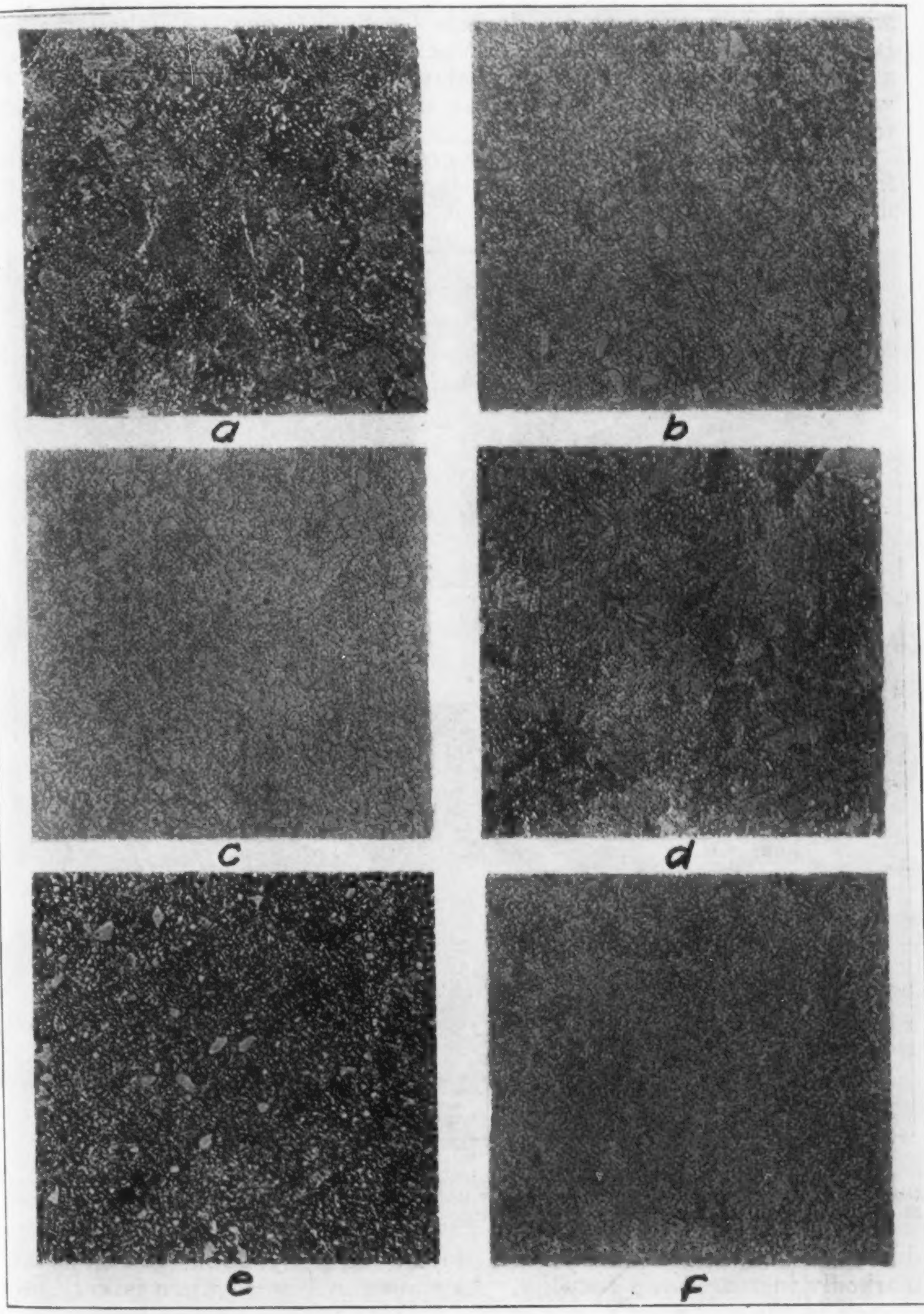

Fig. 13—Microstructure of 1 per cent carbon steel oil quenched from 788 or 843 degrees Cent. and subsequently tempered at different temperatures. Etched with 2 per cent nitric acid in alcohol and X 500. *a* quenched from 788 degrees Cent. and tempered at 316 degrees Cent. *b* quenched from 788 degrees Cent. and tempered at 649 degrees Cent. *c* quenched from 788 degrees Cent. and tempered at 704 degrees Cent. *d* quenched from 843 degrees Cent. and tempered at 316 degrees Cent. *e* quenched from 843 degrees Cent. and tempered at 649 degrees Cent. *f* quenched from 843 degrees Cent. and tempered at 704 degrees Cent.

ments are shown in Figs. 13 and 14 and are of the usual type. After short time tempering at 316 degrees Cent. (600 degrees Fahr.) the steel is troosto-sorbitic and as the tempering temperature increases there is a gradual transition of the ground mass to its more stable form. The water quenched steel, however, has the finest structure regardless of the tempering temperature used.

The effect of soaking at 704 degrees Cent. (1300 degrees Fahr.) when followed by quenching in oil, on the properties of oil hardened steel is shown in Fig. 15 and Table X. A change from ½ to 5 hours has re-

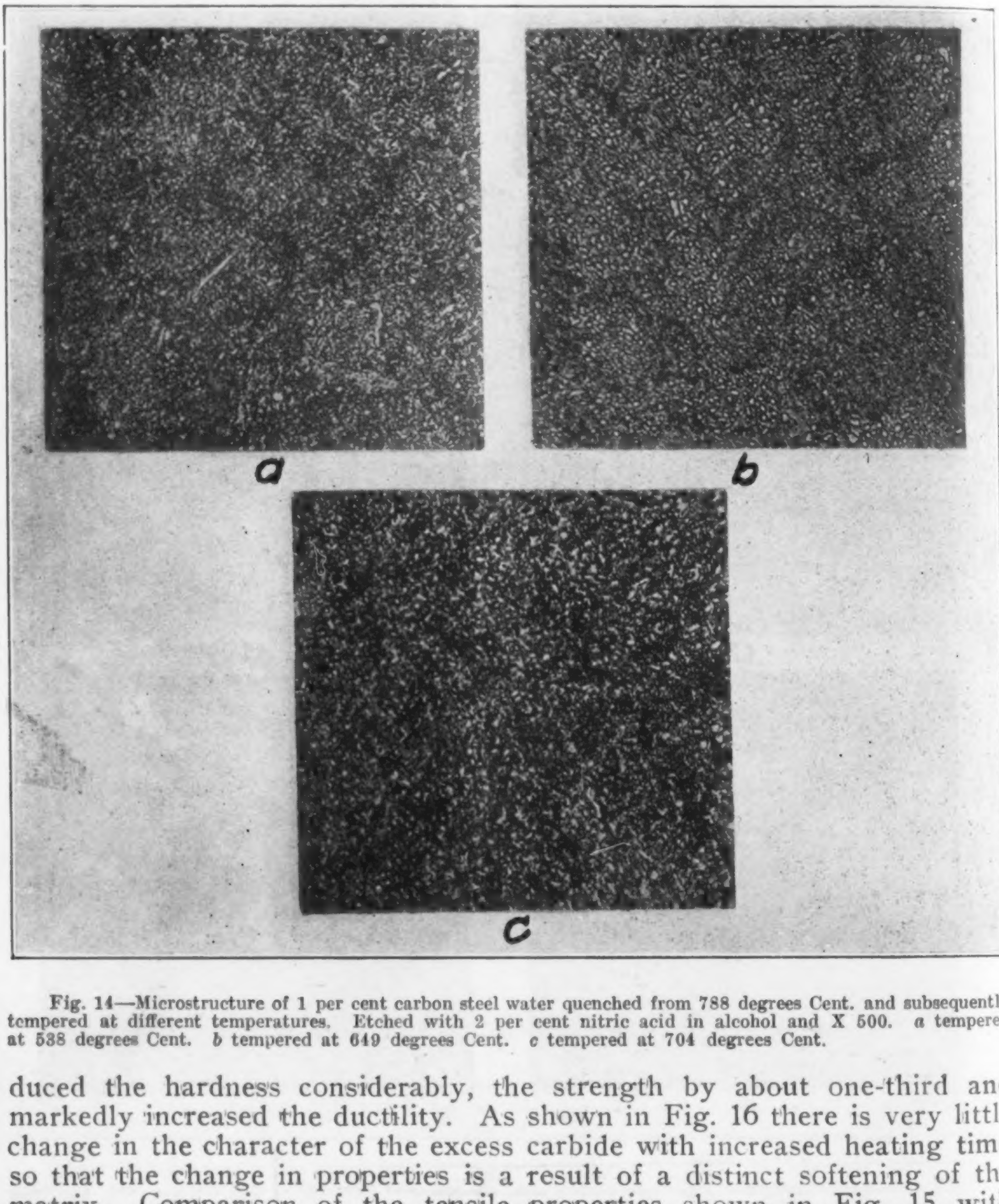

Fig. 14—Microstructure of 1 per cent carbon steel water quenched from 788 degrees Cent. and subsequently tempered at different temperatures. Etched with 2 per cent nitric acid in alcohol and X 500. *a* tempered at 538 degrees Cent. *b* tempered at 649 degrees Cent. *c* tempered at 704 degrees Cent.

duced the hardness considerably, the strength by about one-third and markedly increased the ductility. As shown in Fig. 16 there is very little change in the character of the excess carbide with increased heating time so that the change in properties is a result of a distinct softening of the matrix. Comparison of the tensile properties shown in Fig. 15 with results obtained on normalized steel at once shows the effectiveness of temperatures just under the lower transformation for softening this alloy.

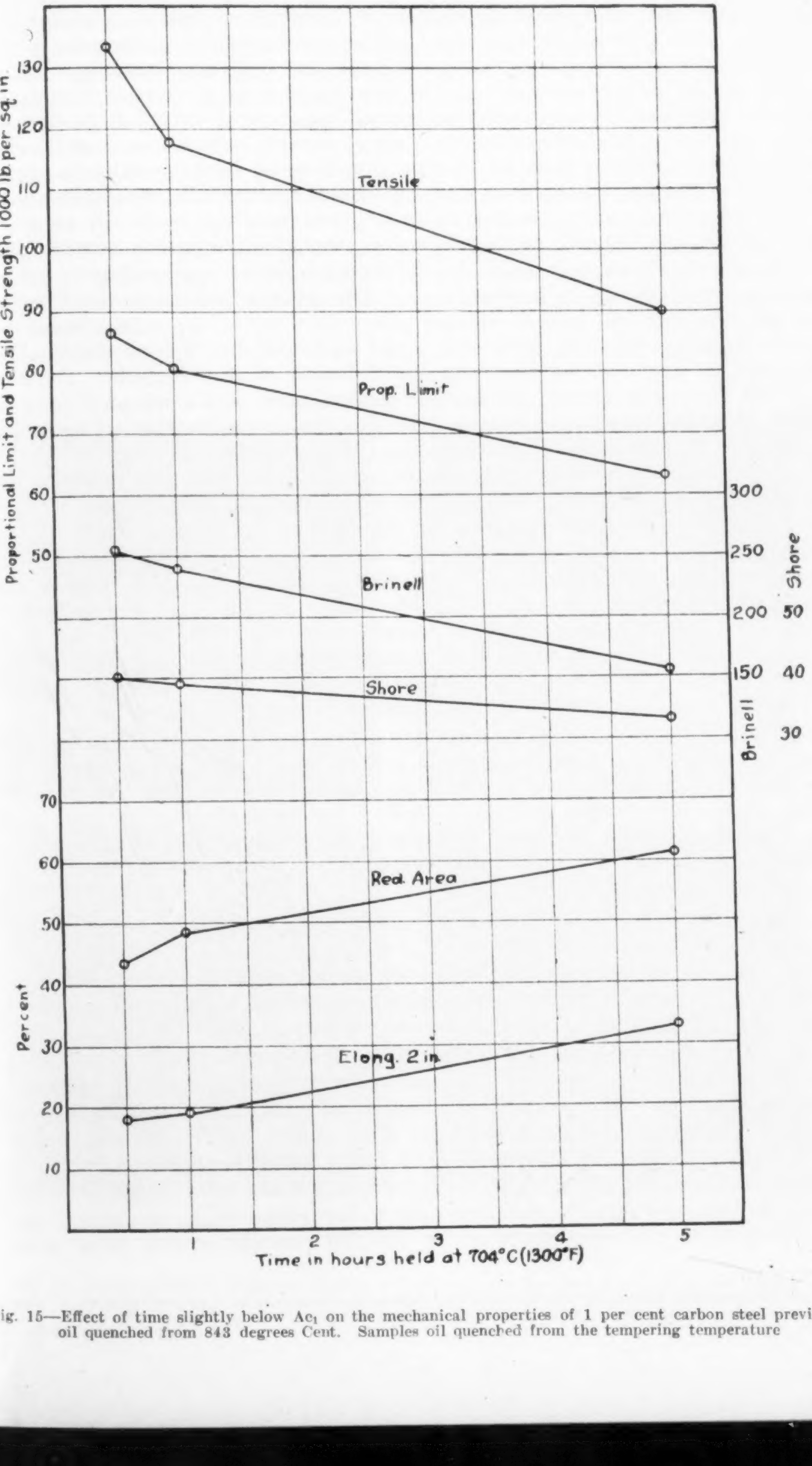

Fig. 15—Effect of time slightly below Ac_1 on the mechanical properties of 1 per cent carbon steel previously oil quenched from 843 degrees Cent. Samples oil quenched from the tempering temperature

As far as the tensile and impact properties of heat treated 1 per cent carbon steel are concerned, certain facts deserve emphasis in connection with the tests previously described. The steel remains extremely brittle even though good combinations of tensile strength and ductility are obtained by suitable treatment. Such low resistance to impact makes the surface condition of the metal of great importance, so that moderately sharp corners, and even scratches may greatly affect the behavior of the steel in service. It is extremely sensitive to heat treatment. Small changes in the hardening temperature produce large differences in tensile properties though after quenching in a given medium as in oil such differences may be largely removed by varying the tempering temperature.

To retail all excess cementite in solution when quenching in oil requires a relatively high temperature. The lowest temperature at which this may be brought about, among other factors, is dependent upon the time of heating prior to hardening, and is lower the longer the soaking but must be at or above the range of solution of this carbide. Between Ac_1 and Acm the excess cementite spheroidizes and coalesces to form larger globules which are retained in the free state in the oil quenched steel. At temperatures slightly below Ac_1 long time heating when followed by cooling in oil produces no change in the condition of the cementite which may be observed readily under the microscope.

In this connection attention is directed to a recent study of the formation of spheroidal cementite by Honda and Saito[23]. The authors conclude that spheroidization of granular pearlite takes place below Ac_1 if held at temperature for a sufficiently long time but that the spheroidization of lamellar pearlite cannot proceed until Ac_1 has been reached or exceeded. If the maximum temperature in heating exceeds a certain limit above this transformation the cementite appears as a lamellar pearlite on cooling and therefore no spheroidization will take place.

The tests carried out in this investigation further indicate the importance of time at temperatures between Ac_1 and Acm as shown in Fig. 9. The sensitivity of 1 per cent carbon steel in this temperature range, within which it is ordinarily heated for hardening to varying time-temperature relations is great and the data obtained show why widely different results may be obtained so readily in the application of the heat treated product.

Based on the tests made under conditions previously described, the following conclusions are drawn:

1. The most suitable oil or water quenching temperature for steel which is subsequently to be tempered at relatively high temperatures is slightly above the end of the Ac_1 transformation.

2. With increase in oil quenching temperature for steel subsequently tempered at 538 degrees Cent. (1000 degrees Fahr.), hardness, strength and limit of proportionality increase and maximum values are obtained after quenching from 843 degrees Cent. (1550 degrees Fahr.) which is coincident with retention of all but a small portion of the excess cementite. A higher quenching temperature results in decreased strength.

3. When this steel is subsequently to be tempered to produce a tensile strength in the neighborhood of 120,000 pounds square inch water

[23] K. Honda and S. Saito, "On the Formation of Spheroidal Cementite." Journ. I. & S. Inst., 1920, Vol. 2, p. 261.

quenching is to be preferred on account of the higher elastic ratio produced, always assuming that the size and shape of material is such as to allow drastic treatment. If higher strength is desired, which condition requires lower tempering, oil quenching from just above the Ac_1 transformation will give slightly better combinations of strength and ductility but with lower elastic ratio than are obtained by water hardening.

4. A lower tempering temperature is required after water hardening than when cooling in oil from the same temperature in order to produce the same strength. This difference in temperature in general increases the higher the strength required, the lower the tempering temperatures.

5. When samples are quenched in water and others quenched in oil and all so tempered as to produce the same strength, the water quenched steel will have the highest hardness as determined by the Brinell and Shore methods.

6. While good combinations of tensile strength and ductility may

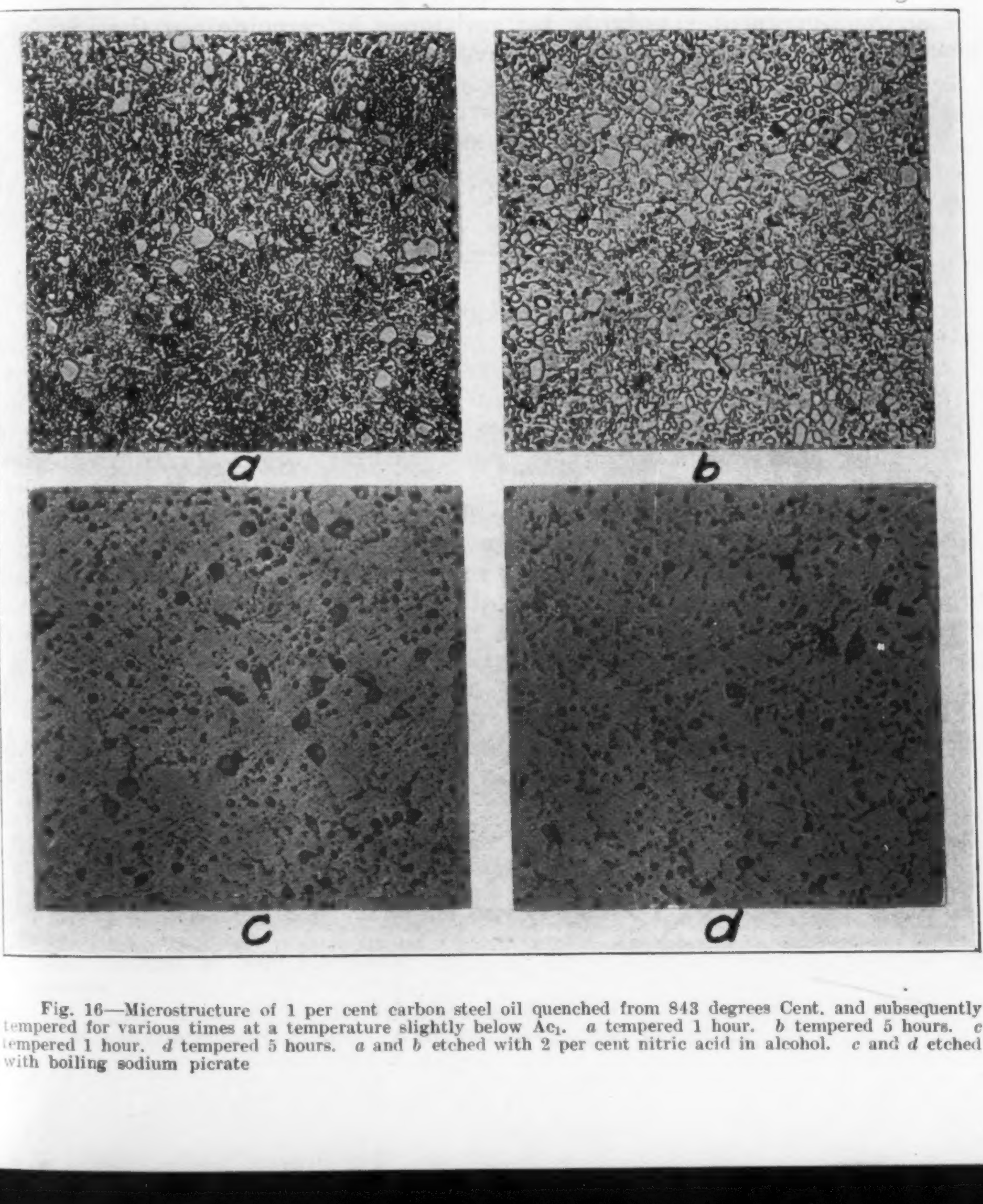

Fig. 16—Microstructure of 1 per cent carbon steel oil quenched from 843 degrees Cent. and subsequently tempered for various times at a temperature slightly below Ac_1. *a* tempered 1 hour. *b* tempered 5 hours. *c* tempered 1 hour. *d* tempered 5 hours. *a* and *b* etched with 2 per cent nitric acid in alcohol. *c* and *d* etched with boiling sodium picrate

be obtained by tempering at the higher tempering temperatures, the steel is brittle and has low resistance to impact. This is shown by the much higher combinations of strength and ductility obtained in tensile tests when the steel is ground to size after heat treatment and by the low Charpy and Izod values obtained in all cases.

7. Increased time at hardening temperatures results in increased hardness, strength and limit of proportionality and decreased ductility as does rise in temperature.

8. Long time heating just under the lower critical range results in a material softening of the steel, equivalent to a decrease of 40 per cent in Brinell hardness and 20 per cent in Shore hardness when the time at temperature is increased from 30 minutes to 5 hours. Short-time heating in this temperature range results in a softer steel than that air cooled from above the transformations.

9. The changes in physical properties which have been described are in all cases coincident with well defined structural changes.

In conclusion acknowledgement is made to T. E. Hamill, laboratory aid of the Bureau of Standards, for assistance in carrying out the various heat treatments and physical tests involved.

DO ALLOY CARBONIZING BOXES PAY?

By C. M. Campbell

THE prime reason for using an alloy carbonizing box is to save money. Any saving of time in handling, both in receiving stores and in the heat treating plant, and uniform quality of carbonizing are a saving of money. In the case of the alloy box this is accomplished by increasing its working life, as expressed in terms of furnace hours, over that of a cast iron or steel box of the same capacity in the same ratio as their unit prices.

Some types of alloy carbonizing boxes, however, work out better than a direct proportion; therefore, if the heat treating plant costs include figures based upon the performance of cast iron or steel boxes, additional savings are obtained. The unit price of alloy boxes is such as to be considered considerably out of line. Although they show long and efficient service, it is difficult to see just why they should not be placed on the supply account instead of becoming a part of the equipment.

Several reasons may be given for this attitude, but before discussing them, we will consider some of the factors governing the life and performance of carbonizing boxes. They may be summed up as follows:

1. Critical points at or below average atmospheric temperatures.
2. Low coefficient of expansion and contraction at high temperatures.
3. Good elastic limit and ductility at high temperatures.
4. Tendency to resist carbon absorption up to and including temperatures of carbonization of steel.
5. Resistance to oxidation.

Resistance to warping and cracking seems to depend largely upon the first two factors mentioned and is independent of the shape of the box. It may be considered also that lack of grain growth is important here. Good heat conductivity is important, but it is characteristic of metals having high coefficient of expansion. The alloy which seems to possess most of these features is one having a nickel base with some chromium and iron.

Several attempts are being made to produce alloys of iron and chromium, an iron base with chromium and silicon 1.5 to 3.5 per cent, the idea being to produce a medium priced box. These alloys resist oxidation as good as nickel-chromium-iron alloys but they will crack at from 600 to 1200 furnace hours, while the alloy which meets the five conditions mentioned above, stands up 3000 furnace hours and better, depending upon the size and shape of the box.

An iron-chromium-silicon alloy which analyzes: Carbon over 0.50, chromium 15.00, and silicon 3.00 per cent show the following properties in the cast condition:

Elastic limit, pounds square inch	45,000-50,000
Ultimate strength, pounds per square inch	53,000-55,000
Elongation in 2 inches, per cent	1.00
Reduction of area, per cent.	2.00
Coefficient of linear expansion, 32 to 212 degrees Fahr	0.0000089
Scleroscope hardness	30-34
Brinell hardness at 3000 kilograms	179-207

A paper presented at the Indianapolis Convention. The author, C. M. Campbell, is superintendent, Pioneer Alloy Products Co., Cleveland.

Ratio of scleroscope hardness to Brinell hardness....................	5.42-6.90
Scleroscope hardness after heating to 1800 degrees Fahr. and air cooling..	40-45
Brinell hardness after heating to 1800 degrees Fahr. and air cooling	364
Ratio of scleroscope hardness to Brinell hardness, specimens heated to 1800 degrees Fahr. and air cooled	9.1-8.56

This material has some toughness as shown by the scleroscope and Brinell hardness but when heated to 1800 degrees Fahr. and air cooled it loses its toughness and becomes brittle. As a result the carbonizing boxes crack.

In practice, using a square carbonizing box weighing 55 pounds, having a uniform wall thickness of ⅜-inch and round corners with ⅝-inch radius, resistance to oxidation, warping and cracking is good up to 400 furnace hours. Beyond that time cracking takes place, and a slight warping in the bottom of the box is noticed; this occurring usually around 600 furnace hours. In all instances of cracking, one crack appears down the side of the box. In some cases, this starts as a surface crack and gradually works through the wall in 600 to 1100 furnace hours.

In one case out of eight, the carbonizing box was used 1400 furnace hours and showed no signs of scaling and cracking, but slight warping occurred in the bottom. When heated to 2200 degrees Fahr. and furnace cooled, a box showed a scleroscope hardness of 20 and a Brinell hardness of 149, the ratio being 7.45. When reheated to 1800 degrees Fahr. and air cooled, it showed a scleroscope hardness of 15 and a Brinell hardness of 143 with a ratio of 9.53. No decrease in hardness was shown but brittleness increased. Cooling from 2200 degrees Fahr. forms a solid solution structure which is not produced at temperatures under 2000 degrees Fahr., the metal being in the cast condition. This iron-chrome-silicon alloy can be cast in either green or dry silica sand molds when the carbon content is less than 0.25 per cent.

It seems to be on account of the relatively high price of such an alloy that objections to its widespread use is based. These objections have their origin in the kind and amount of material being carbonized and as to whether the business is jobbing or specialty, and if the latter, whether the heat treated work is of one kind or diversified. The jobbing shop will carbonize a variety of steel parts on numerous small and large orders. Thus it is necessary to have on hand several different sizes of boxes, many of which are in use only at long intervals. It would seem, in this case, that a stock of high priced carbonizing boxes would unduly burden equipment and depreciation accounts.

In cases where the shop will have large orders for one or more different kinds of articles, it may be decided to charge the cost of the alloy boxes to be used against each order. For example on an order for a quantity of case hardened bolts, it is found that the required number of carbonizing boxes at 10 cents per pound will add ¼ cent to the cost of each bolt. If the box cost $1.25 per pound, it will raise the cost on each bolt to some 3 cents. If the value of the bolts is small and competition keen, such a price may be out of the question. Here, the most important factors to be considered are: The value of the product, and strength and amount of competition.

The conditions in a specialty shop are quite different from those prevailing in a jobbing shop. In this case, the amount and value of each kind of article to be carbonized is known in advance and, although the

charge per furnace hour varies with the size of the boxes, an increase in their life decreases the charge per furnace hour as shown by the following figures:

Weight of box pounds	Price per pound	Total cost	Furnace hour charge	Furnace hour life
45	$1.25	$56.25	0.938c	6000
45	1.25	56.25	0.803	7000
45	0.40	18.00	1.500	1200
45	0.40	18.00	1.285	1400
45	0.40	18.00	0.900	2000
45	0.10	4.50	1.125	400
45	0.10	4.50	1.000	450

Now suppose we take a box weighing 50 pounds and it is shown that its life is 6000 furnace hours. The initial investment will be some $56.00, and the furnace hour minimum being 6000, the charge per furnace hour will be 0.93 cents. If you should get 7000 hours out of that, the price would drop to 0.80 cents. If you were using at the same time for that same class of work, and on that same class of order, a 45-pound box, which costs 10 cents a pound, the initial investment is $4.50, and the charge per furnace hour would be 1.125 cents. If you should get 450 furnace hours, it would drop to 1.00 cent. Now if you use the alloy just described, the iron-chrome-silicon, which may sell at this time for some 40 cents per pound, you would have an initial investment of $18.00. But the best we can do, perhaps, out of that is 1200 furnace hours, so it would cost 1.50 cents per furnace hour. If that increases to 1400 furnace hours, it would bring it to 1.285 cents, and if you should by any chance go to 2000 furnace hours, it would drop to 0.90 cents.

The value and amount of a given article affect the kind of carbonizing box to use. For a given kind of carbonizing box a decreasing value of the article increases the number to be carbonized in order to pay for the box, as shown as follows:

Unit charge	Cost of box	Number of pieces
00.75c	$10.00	1333
00.50	$10.00	2000
00.25	$10.00	4000

The selling price of the product usually includes a large enough gross profit to make possible the addition of a fraction of a cent or a few cents to the production cost of the article, or the addition of another item to equipment and depreciation costs without decreasing net profits, because these additional charges are offset by economies in other directions due to the use of the alloy box. When these charges are more than offset, the difference is an addition to net profits. Owing to the conditions in the jobbing shop, which prohibit the extensive use of alloy boxes, it has been suggested that such boxes be sold on the basis of service.

Now it would seem that if you would charge on a basis of service, you carry that out, for instance, like the United Shoe Machinery Co.'s, which rent shoe machinery to individuals. It makes possible the use of shoe machines even in the small repair shops. But the same applied to carbonizing boxes would require service stations located at points such as Pittsburgh, Cleveland, Indianapolis, Chicago and other points, and a warehouse carrying in stock a large number of different size boxes, this stock being determined in advance by a study of the requirements of

those neighborhoods. When an operator wished to have a box for his plant, he would call up the service station and get the required number. If he had an order for a certain number of articles and he had no boxes; he would know from that order about what size boxes he needed, how many, and the length of time required to carbonize the work, and he would know in advance the charge for the service. He could add that on to the cost of carbonizing and would know in advance just what his total costs would be. If he did not need the boxes for further work, he could send them back to the service station. However, that service charge will have to include the cost of boxes in stock at the service station, and that might run pretty high. In addition, the fact that it is fundamental in all businesses that you have to have a large enough gross profit in order to establish the business in a given locality, one could not say at this time just what it would cost for service on that basis.

It is also seen here from the conditions outlined in the tables, that with a study of the subject of costs along that line, each individual heat treater or each manager of a heat treating plant, could apply these tables in his own plant. The writer knows of two different plants manufacturing substantially the same kind of parts, operating on practically the same monthly capacity of parts in their heat treating plants. One operates in such a manner that a hard cast iron box will last an average of 150 hours on carbonizing, for example on cam shafts, the nickel-chrome alloy box will last not over 1800 furnace hours. In the other plant, which does a similar line of work, a hard cast iron box lasts better than 400 furnace hours, and the nickel-chrome alloy box lasts something over 2000 furnace hours. Both plants operate with the same kind of heat treating equipment.

From these tables it will be seen that the plant which has the lowest rate or lowest furnace hour life for its carbonizing boxes could use for carbonizing cam shafts a nickel-chrome alloy box, on which the price is of course high, but money could be saved because the cost per furnace hour is greatly reduced over that of hard iron boxes.

Discussion of Mr. Campbell's Paper

MR. PORTER: Can the alloy box be made as light as a hard cast iron box? My reason for asking that is that in one particular case a man has to pick up the box from the floor, put it on a bench, pack it and shift it on to a truck. He has no time to use mechanical equipment to do it. The alloy box that I bought weighs 75 pounds, as against 40 for the hard cast iron box.

MR. CAMPBELL: These alloy boxes can be made lighter than the hard iron box. The reason for that is that the physical properties of the nickel-chrome alloy are somewhat different from those of the iron. The hard cast iron, so-called, is brittle and thin sections seem to crack. Foundry practice, at the present time at least does not permit you to get the same thin sections with cast iron as you would with the nickel-chrome alloy, for the reason that you have a high expansion and high liquid contraction of cast iron, and unless you use a shell core, that is, a core made with a hollow center and very thin wall, it will be found almost impossible to get the same thin section that you can with the

nickel-chrome alloy. A box that weighs some 70 pounds in cast iron, can be made to weigh about 55 pounds, when cast with alloys.

MR. GORDON: You spoke about having the same condition in the two plants and getting a different life of the pots. Was that due to cracking or due to scaling or what seemed to be the cause of that? Was it a difference in the kind of fuel they were using or difference in regulation of the heat, or what?

MR. CAMPBELL: They didn't have the same conditions in the two plants. The policy of the management of one plant seemed to be to rush things through rapidly. This rushing process seemed to decrease the unit cost of manufacturing the article. However, the principal reason was, I think, that the article that they were making, the assembled article, was somewhat lower in cost than the article manufactured by the company that ran their plant cheaper on carbonizing boxes. As to warping and cracking, the conditions that cause warping and cracking are the same in all plants, but in this particular case where the work was rushed through, the warping and cracking occurred quicker than it would in the other plant.

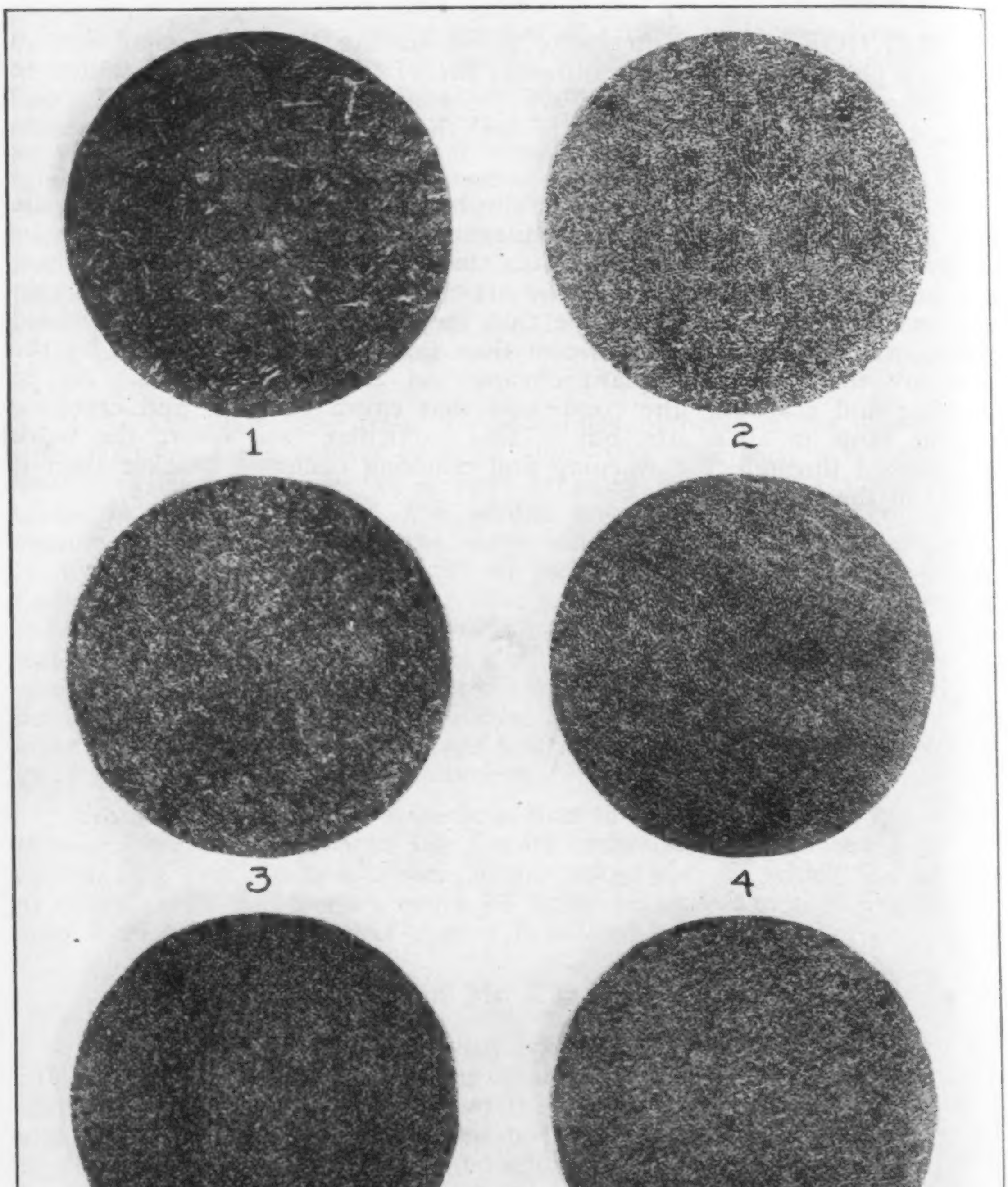

Fig. 1—Composition 254, nickel-silicon steel. Fig. 2—Composition 389 steel. Fig. 1 presents quite a contrast to Fig. 2, the latter being a more uniform steel and extremely well knit together in the arrangement of its constituent alloys. Fig. 3—Composition 390, reveals the structure when the nickel is doubled and the silicon increased 30 per cent. Fig. 4—Composition 530-1, shows the structure obtained by reducing the silicon one-half. Fig. 5—Composition 531-1, modified by zirconium. Fig. 6—Composition 532-1, containing titanium as stated

SOME ALLOY STEELS OF HIGH ELASTIC LIMIT, THEIR HEAT TREATMENT AND MICROSTRUCTURE

By Charles M. Johnston

AN INVESTIGATION was begun during the late European war for the purpose of developing the best light armor plate for the protection of gunners and airplane pilots. The best steel for the light plates, that is 0.2 to 0.5-inch thick, and probably the best steel of its kind at that time, was silico-nickel steel of 0.35 to 0.60 per cent carbon.

The demand arose for a still better steel to withstand increased striking velocity. Also ammunition charges were increased and types of cartridges of greater penetration were used. With a view to meeting these increased requirements as far as possible with silico-nickel steel as the fundamental composition, the effect of modifying this basic analysis by the addition of vanadium and chromium was tried. This addition of vanadium and chromium is now patented. The best heat treatment of the silico-nickel steel gave about 274,000 pounds per square inch, ultimate strength, 237,000 pounds per square inch, yield point, 11½ per cent elongation, 36 per cent reduction, and a 555 Brinell.

But upon the addition of chromium and vanadium, an ultimate strength of 290,000 to 310,000 pounds per square inch, 260,000 to 280,000 pounds per square inch yield point and 6 to 10 per cent elongation were obtained, with a Brinell hardness of 512. These good figures were reflected by improved showing in ballistic tests. As a result of experience gained during the war, the military authorities, especially for protection of air pilots, made requests for still greater strength in plates. This caused further experimenting until finally the silico-nickel composition was modified by increased amounts of chromium and vanadium and also by the addition of tungsten, zirconium, titanium and molybdenum in various combinations. It is not the purpose of this brief article to dwell on the ballistics obtained except to state that among the various compositions, about the best ballistics were secured from ¼-inch plates highly alloyed—one of the silico-nickel types containing molybdenum.

It should be said that the molybdenum content was so much overshadowed by the percentage of the other nonferrous elements that it cannot be assumed that the molybdenum was the cause of the improved showing. Of course the disciples of molybdenum will agree that it is most likely the master alloy in this case. For their further encouragement, the composition known as 491 can be considered as practically as good as the 490. It contained one-half as much molybdenum as 490.

The following are the best tensiles obtained from compositions 490 and 491:

	Composition		
	490	491	491
Quench (Oil), degrees Fahr.	1600	1600	1600
Draw, degrees Fahr.	1000 (½ hour)	1200 (1 hour)	1000 (½ hour)
Ultimate strength, pounds per square inch	276,260	193,910	275,000
Yield point, pounds per square inch	253,450	153,330	213,780
Elongation in 2 inches, per cent	Nil	12.5	2.5
Reduction in area, per cent	2.2	33.1	Nil
Brinell hardness	512	418	477

A paper presented at the Indianapolis Convention. The author, Charles M. Johnson, is director of research department, Crucible Steel Co. of America, Pittsburgh.

Also a composition known as 389 gave the following:

	Composition 389	
Quench, degrees Fahr.	1600	1600 (in oil)
Draw, degrees Fahr.	1000 (½ hour)	1200 (½ hour)
Ultimate strength, pounds per square inch	293,180	167,830
Yield point, pounds per square inch	280,110	157,780
Elongation in 2 inches, per cent	10.0	17.0
Reduction in area, per cent	31.5	47.5

Compositions 389 are splendid looking tensile strength specimens, showing three-quarters to complete cup, tough fracture and having 10 per cent elongation, even at 555 Brinell hardness. The foregoing yield points were taken with dividers and were from plate tests. These results from compositions 389, 490 and 491 suggested that a series of tests be made with rolled bars, 1 to 1½-inch rounds. The bars for this purpose were 389 composition, also the latter composition in which the silicon was increased 20 per cent and the nickel doubled (390-3), an ingot in which the silicon was reduced 50 per cent (530), one in which the silicon was reduced 50 per cent and about 1 per cent zirconium added to this reduced silicon (531), one in which the silicon was decreased two-thirds and 1 per cent of titanium added (532-1), one in which the silicon was reduced two-thirds and 0.6 per cent of titanium added (532-2), one in which the silicon was reduced two-thirds and less than 1 per cent of molybdenum added (534-1) and one in which the silicon was reduced two-thirds and less than 1 per cent of tungsten added (535-1).

The tabulations in Table I show the results of heat treating these steels. The test specimens were heat treated in 0.505-inch section and held at quenching temperatures 20 minutes after reaching the temperature of the furnace. The section was taken from the central portion of the bar. No record is given here of the various treatments used and physical properties, except those that were found to give elongations ranging from 5 to 10 per cent, consequently the tabulations are brief and do not reveal a considerable quantity of work done to arrive at the figures.

From the results in Table I, the following deductions can be made: First, that there is no apparent improvement in physical strength, at least as revealed by the tensile machine, by doubling the nickel content as shown by composition 390 compared with 389. Second, the table shows that the 389 composition is markedly superior to the 254 which is the well known silico-nickel composition.

Table II shows values obtained from zirconium and titanium steels. It does not reveal any superiority over the 389 steel which is a cheaper composition.

The results in Table III are especially interesting in that they are from two steels that are with the exception of one element, as much alike analytically as two peas in a pod, that is two peas that are alike. Anyone who has shelled peas knows that two peas in the same pod may be alike in complexion and general contour but not necessarily in size. These compositions, to be exact, are alike, but with the exception that one steel contains 0.7 per cent of molybdenum and the other contains 0.7 per cent of tungsten, with 389—silicon reduced two-thirds—as the basic composition. The molybdenum steel is 534-1, the tungsten steel is 535-1.

There is no marked difference in the physicals except perhaps elonga-

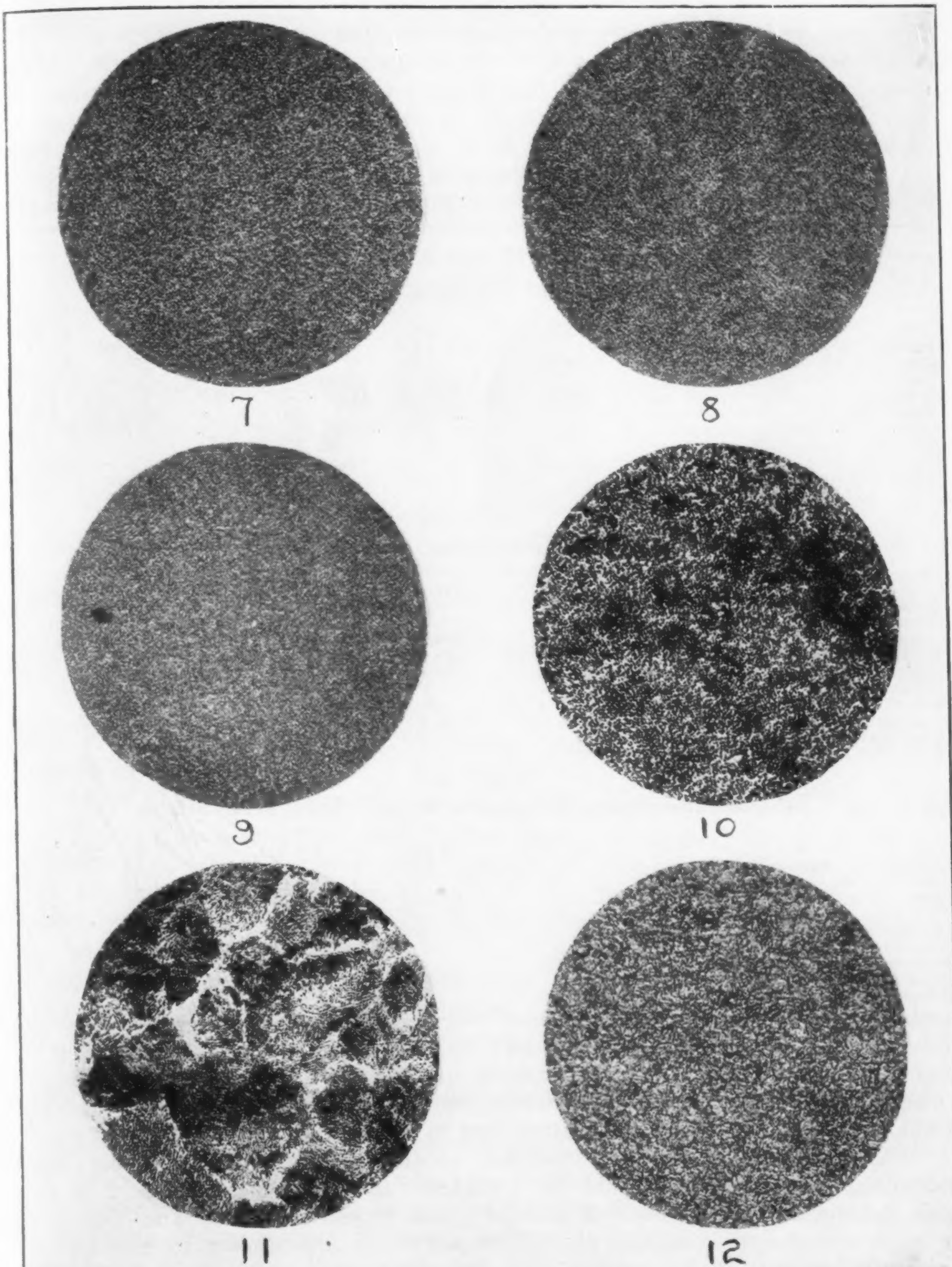

Fig. 7—Composition 532-2, containing titanium as stated. The structures of compositions 390, 530-1, 531-1, 532-1, and 532-2 present marked similarity and microstructure. Fig. 8—Composition 534, of molybdenum content. Fig. 9—Composition 535, of tungsten content. The molybdenum and tungsten steels are referred to as being practically alike in composition, except in the items of molybdenum and tungsten. The microstructures of Figs. 8 and 9 apparently are almost identical in the heat treated state. Fig. 10—Composition 389 annealed. Elastic limit, 109,010 pounds per square inch; ultimate strength 144,450 pounds per square inch; elongation 17.5 per cent; reduction in area 29.7 per cent; fracture flat; Brinell 286. Fig. 11—Composition 254 annealed. Elastic limit 90,950 pounds per square inch; ultimate strength 136,900 pounds per square inch; elongation 3.5 per cent; reduction in area 4.7 per cent; fracture flat; Brinell 321. Both the photomicrographs and tensile figures demonstrate superiority of composition 389 over the 254 in annealed state as well as in hardened and drawn state. Fig. 12—Microstructure of high speed type of high elastic limit that falls into this class on account of its high elastic limit and good elongation

tion and reduction are a little better in the molybdenum steel. The molybdenum steel also has the advantage that it can be made in the open-hearth furnace, whereas the tungsten steel must be made either in the electric or crucible furnace. It is rather surprising that there is so little difference in the values, at least as revealed by the tensile machine.

A further investigation is planned to test these two steels for their torsional, impact, bending qualities, and for modulus of elasticity, etc.

Table I
Results of Heat Treating Various Steels

	Composition					
	254	254	389	389A	390	390
Quench (Oil), degrees Fahr.	1450	1600	1600	1550	1600	1550
Draw (1 hour), degrees Fahr.	1750	800	650	600	600	600
Elastic limit, pounds per square inch	231,700	231,950	249,500	247,770	233,000	226,400
Yield point, pounds per square inch	241,570	237,100	259,160	257,700	243,000	231,500
Ultimate strength pounds per square inch	255,660	274,740	311,690	308,900	295,900	291,400
Elongation in 2 inches, per cent	5.5	11.0	11.0	11.0	11.0	10.5
Reduction in area, per cent	23.2	36.8	42.9	39.5	27.2	26.9
Fracture	¾ Cup	¾ Cup	¾ Cup	Full Cup	¾ Cup	½ Cup
Brinell hardness	512	555	555	555	555	555

Table II
Test Values from Zirconium and Titanium Steels

	Composition				
	531-1Zr	532-1Ti	532-2Ti	530-1	530-1
Quench (Oil), degrees Fahr.	1550	1600	1600	1600	1550
Draw (1 hour), degrees Fahr.	750	600	600	600	750
Elastic limit, pounds per square inch	258,700	241,300	218,000	270,440	277,500
Yield point, pounds per square inch	263,800	256,200	232,000	280,000	282,450
Ultimate strength, pounds per square inch	306,900	280,950	265,300	330,550	308,200
Elongation in 2 inches, per cent	8.0	8.5	9.0	5.0	6.0
Reduction in area, per cent	28.4	29.7	37.7	10.4	19.4
Fracture	¾ Cup	½ Cup	Full Cup	Flat Break	¾ Cup
Brinell hardness	555	477	477B	555	555

Table III
Test Values from Molybdenum and Tungsten Steels

	Composition			
	534 Mo.	534 Mo.	535 W.	535 W.
Quench (Oil), degrees Fahr.	1600	1650	1600	1650
Draw (1 hour), degrees Fahr.	650	650	650	650
Elastic limit, pounds per square inch	222,650	212,650	218,660	220,370
Yield point, pounds per square inch	227,480	217,810	223,510	225,270
Ultimate strength, pounds per square inch	269,360	270,570	265,790	270,560
Elongation in 2 inches, per cent	10.5	12.5	10.5	10.5
Reduction in area, per cent	42.8	45.1	41.4	40.0
Fracture	Full Cup	¾ Cup	¾ Cup	Full Cup
Brinell hardness	512	512	2	512 51

Also it will be an interesting study to determine at what point a gradual equal increasing of molybdenum on one hand and tungsten on the other would begin to show marked differences in the tensile and other physical properties and microstructure of these two types of steel.

A tungsten-chromium-vanadium steel that has been giving most excellent service in the trade for a number of years is interesting in this connection, in that it shows similar good physical values and yet is of a high speed type of analysis. The physicals are shown in the following tabulation:

Quench (Oil), degrees Fahr.	2200
Draw (1 hour), degrees Fahr.	1100
Elastic Limit, pounds per square inch	223,690
Yield point, pounds per square inch	245,820
Ultimate strength, pounds per square inch	256,630
Elongation in 2 inches, per cent	8.5
Reduction in area, per cent	26.8
Fracture	½ Cup
Brinell hardness	477

This well tried steel can be consistently classed in high elastic range with 9 to 10 per cent stretch.

The steels discussed in this article anneal best by being held at temperatures ranging from 700 to 740 degrees Cent. (1292 to 1364 degrees Fahr.) after normalizing at 900 degrees Cent. (1650 degrees Fahr.). Hardening ranges are shown by the tables from 1500 to 1650 degrees Fahr. for compositions 389, 390, 530, 531, 532 and 534, and

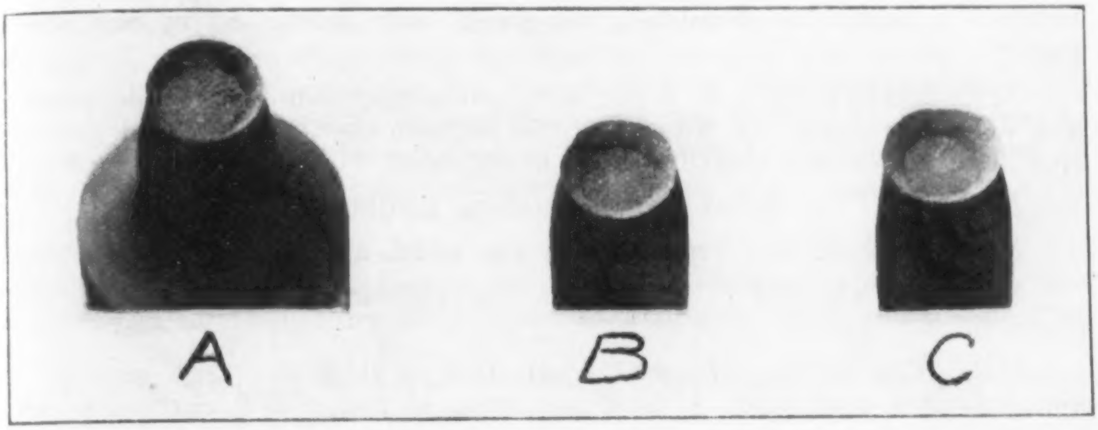

Fig. 13—Photograph showing typical test specimens of high elastic limit steels. *A* is 389 composition, tempered in oil at 1550 degrees Fahr. and drawn at 600 degrees Fahr. *B* is 534 composition, tempered in oil at 1600 degrees Fahr. and drawn at 650 degrees Fahr. *C* is 535 composition, tempered in oil at 1650 degrees Fahr. and drawn at 650 degrees Fahr.

1650 degrees Fahr. for 535. Forging temperatures 1850 to 1950 degrees Fahr.

Microstructures of heat treated cross sections are shown in Figs. 1-13.

The entire non-high-speed series herein described show much improvement over the older high grade silicon-nickel composition 254, and are most promising by reason of the tensile values given in the tables, and by reason of the uniform, tough and dense microstructure of the heat-treated condition.

The physical properties of all these compositions promise much for such purposes as high grade punches, cold sets, chisels, heading dies, rivet sets, automobile axles and springs.

Discussion of Mr. Johnson's Paper

MR. D'ARCAMBAL: About what does the carbon run in those?

MR. JOHNSON: The range is from 0.39 to 0.66 per cent carbon. We found when this steel is treated as described in the foregoing, that the carbon did not have as much influence on the tensile properties as might be expected. We tried one silico-nickel combination in which the carbon was 0.46 per cent. After treating it, we obtained nearly as high figures as we did with 0.66 per cent carbon steel. The alloys seemed to overshadow the carbon content when the steel was treated with a view to getting the highest elastic limit.

MR. D'ARCAMBAL: In looking at some of those figures, the figures resemble those you can get on some of the tougher gear steels.

MR. JOHNSON: Steel of this type might come in under that ap-

plication. You get such good reduction with a 10 per cent elongation that it has possible applications in several lines.

MR. NORTON: Will you kindly explain why you infer that your molybdenum might be a master alloy in that particular composition?

MR. JOHNSON: I did not say that. I said those that were interested in molybdenum might assume that it is a master alloy.

MR. FOLEY: I would like to know why you kept the elongation between 5 and 11. Wouldn't you have been interested in one above that?

MR. JOHNSON: If I got a bigger elongation the tensile properties would be lower. I was after the highest elasticity I could get and still have something measurable in elongation.

MR. SCOTT: What was the etching medium used?

MR. JOHNSON: The ordinary one used, alcohol and nitric acid.

MR. KLINKETT: What was the chemical analysis of the 389 composition?

MR. JOHNSON: It was from 0.40 to 0.60 per cent carbon, in round figures and from 1 to 2 per cent silicon, 0.075 chromium and 0.20 to 0.30 per cent vanadium. Three per cent nickel, of course, entered into it.

PROPERTIES OF SOME STEELS IN THE HARDENING RANGE

By W. R. Chapin

IN THIS paper the term "hardening range" is meant that temperature range within which quenched steel acquires its maximum hardness as tested with the Brinell machine, scleroscope or file. This report applies only to those steels which, when properly quenched, harden throughout the mass, or as it may be expressed, harden "solid" and are martensitic when so hardened.

It is not claimed that this maximum hardness is the greatest hardness possible to obtain in these steels for it is well known that an even greater hardness is made possible by the use of certain quenching mediums and certain high temperatures. The maximum hardness referred to is the greatest hardness obtainable by the employment of commonly used quenching oil or plain water, the quenching temperatures being such as are used in good common practice.

By reference to test No. 1 it will be noted that this specimen which was ½-inch square was 192 Brinell in the annealed condition. The specimen was quenched in oil from a temperature of 1475 degrees Fahr. and taken from the oil in the hardening range.

It will be appreciated readily that the temperature of the piece when taken from the oil is difficult to measure accurately, particularly near the surface. It may be stated, however, from a great many tests removed from the bath in the hardening range and quickly polished for Brinell testing that the color appearing on the polished surface would indicate strongly that this temperature lies between 400 and 500 degrees Fahr.

It is respectfully suggested to those who have sufficiently delicate apparatus and the inclination that this hardening range temperature may be accurately plotted pyrometrically. This may be done by placing a sensitive couple in the center of a piece, protecting the couple by means of a copper tube brazed into the piece and attaching the couple to a sensitive instrument which will record rapid temperature changes.

Specimen No. 1, it will be noted, was 192 Brinell in the hardening range, practically file hard and could be readily deformed. It shrank 0.009-inch in the hardening range and in cooling in the hardening range naturally in the air to the cold, by which is meant room temperature, it expanded 0.011-inch and was 652 Brinell when cold. It will be noted that it expanded only 0.002-inch from the annealed to the cold state. No. 1 is a well known oil hardening, so called "nonshrinking" steel, but as a matter of fact the steel did shrink 0.009-inch in the hardening range and then expanded 0.011-inch in that range.

It is to be noted particularly that specimen No. 1 was entirely unaffected by a powerful horseshoe magnet in the hardening range. This fact was first observed by the writer's assistant W. L. Appel. It is to be noted that this loss of magnetism in the hardening range is most noticeable immediately after withdrawing from the quenching bath and further that there is a gradual return of the magnetic property as the steel cools through the hardening range to the cold. It is also interesting to note that with the gradual return of the magnetic property the Brinell hardness also gradually rises.

The appearance of the Brinell indentation in the hardening range is

A paper presented before the Cleveland Chapter. The author, W. R. Chapin, is director of the testing department, E. C. Atkins & Co., Indianapolis, and president, Deeds & Chapin, Indianapolis.

peculiar in that it is not clear cut but there is a rounding off entirely around the periphery. This appearance is characteristic of all the steels tested in the hardening range.

Referring to test No. 3 it will be seen that this specimen also shrank in the hardening range and showed even a lower Brinell than in the annealed state. No. 3 was also nonmagnetic in that range, could be readily deformed and was practically file hard. It also expanded from the hardening range to the cold and was 652 Brinell when cold. This specimen was a round disk 0.156-inch thick.

In order to determine the Brinell hardness of tests Nos. 1 and 3 in the center of the bar, other samples from the same bars were quenched and brought out in the hardening range, broken and Brinell tested in the center. These pieces were 192 Brinell in the center, practically file hard in the center and were 652 when cold. This test was made repeatedly with the same result each time. Attention is called to test No. 2, which is a well known water hardening steel. The sample was ½-inch square. It will be noted that No. 2

Chemical Analyses of Test Specimens

Test No.	Carbon per cent	M'g'ese per cent	Silicon per cent	Sulphur per cent	Ph'phorus per cent	Chrom'm per cent	Vanad'm per cent	Nickel per cent
1	0.770	1.48	0.407	0.021	0.006	0.06	0.19	...
2	1,070	0.28	0.404	0.022	0.010	...	...	...
3	0.800	0.35	0.200	0.020	0.020	0.40	...	1.25
4	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
5	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
6	1.070	0.28	0.404	0.022	0.010	...	...	...
7	1.070	0.28	0.404	0.022	0.010	...	...	...
8	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
9	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
10	1.070	0.28	0.404	0.022	0.010	...	...	...
11	1,070	0.28	0.404	0.022	0.010	...	...	...
12	0.780	0.39	0.146	0.014	0.023	0.32	...	1.36
13	1.044	0.48	0.118	0.034	0.010	0.50	...	1.37
14	1.112	0.29	0.192	0.023	0.016	...	...	...

expanded continually in the hardening range until cold and was plainly magnetic in that range.

Referring now to test No. 14 it will be seen that this also is an ordinary water hardening tool steel. This steel when quenched in water, as in common practice, is magnetic in the hardening range and expands continually until cold. A specimen cut from bar No. 14 failed to harden in oil in the original size which was ¾-inch wide by 3/16-inch thick but hardened very readily in water.

When bar No. 14 was machined down to 0.050-inch thick, it will be seen that it hardened in oil readily and exhibited all the characteristics of a true oil hardening steel, that is, in the hardening range it first shrank, then expanded, showed a low Brinell gradually increasing and was nonmagnetic. On the other hand, a piece from bar No. 1 when quenched in water and brought out in the hardening range was distinctly magnetic, was file hard, showed a low Brinell and acquired maximum Brinell when cold.

Tests Nos. 12 and 13 are average specimens from 100 tests. They are very interesting in that they show that in the hardening range these steels shrank in every dimension and then expanded in every dimension as they approached the cold. Furthermore these steels shrank upon drawing. No. 12

in the hardening range first shrank 0.195-inch in length and 0.010-inch in width and then expanded 0.232-inch in length and 0.012-inch in width and upon drawing to 800 degrees Fahr., No. 12 shrank 0.236-inch in length and 0.006-inch in width. No. 13 in the hardening range shrank 0.193-inch in length and 0.013-inch in width and then expanded 0.219-inch in length and 0.017-inch in width. In drawing to 800 degrees Fahr., No. 13 shrank 0.128-inch in length and 0.004-inch in width.

No. 12 was 0.100-inch thick and No. 13 was 0.090-inch thick. The change of thickness in the hardening range is not reported on account of the difficulty in getting an accurate measurement on account of rolling scale coming off and on account of getting an accurate record of such a small change as would take place in the thickness. But since these 100 pieces shrank in two dimensions and then expanded in two dimensions it is perfectly logical to expect that they also contracted and then expanded in the third dimension. The 100 specimens were nonmagnetic in the hardening range.

Another specimen from No. 12 and No. 13 was given the same treatment and after being drawn to 800 degrees Fahr. was annealed to produce a pearlitic structure. The measurements were then found to be practically the same as originally. By reference to tests Nos. 4 to 11 inclusive, it will be seen that the rate of cooling from the hardening range to the cold does not affect the ultimate hardness when cold.

A piece from bar No. 1 was quenched in oil and was allowed to cool from the hardening range to the cold in a patented compound requiring an hour to cool. Specimen No. 1 was 192 Brinell in the hardening range and 652 Brinell when cold. It is apparently true moreover that there is less distortion and less ultimate change of volume if these steels are allowed to cool slowly from the hardening range to the cold than when allowed to cool in the quenching bath as in common practice.

It is to be noted that specimen No. 4 was quenched in oil until cold and then drawn at 400 degrees Fahr. in oil for 15 minutes. After drawing it was allowed to cool in the air and was 652 Brinell both before drawing and after drawing. After drawing it could be filed slightly. No. 4 was then drawn again for 15 minutes at 400 degrees Fahr. in oil and after drawing when cold was 627 Brinell and could be filed easily.

No. 5 was quenched in oil from 1500 degrees Fahr. the same as No. 4 but taken out in the hardening range and drawn at once at 400 degrees Fahr. in oil for 15 minutes. It will be seen that No. 5 was 192 Brinell in the hardening range and was nonmagnetic. After drawing 15 minutes it was 652 Brinell and could be filed slightly. No. 5 was then drawn 15 minutes more at 400 degrees Fahr. in oil and after drawing was 627 Brinell and could be filed easily.

By referring to No. 6 it will be noted that it Brinell tested 179 in the annealed state and upon quenching in water from 1440 degrees Fahr. until cold it expanded 0.013-inch in length and was 683 Brinell when cold. No. 6 after drawing 15 minutes in oil at 400 degrees Fahr. contracted 0.004-inch in length and was 627 Brinell.

It will be seen that No. 7 quenched the same as No. 6 but taken out in the hardening range was 302 Brinell in that range, was magnetic and was practically file hard. No. 7 upon drawing 15 minutes in oil at 400 degrees Fahr. was 627 Brinell and could be filed readily. It will be noted that No. 7, which was cut from the same bar as No. 6, expanded 0.005-inch from the annealed to the cold state whereas No. 6 quenched regularly expanded 0.009-inch from the annealed to the cold.

Referring to test No. 8 it will be seen that after quenching regularly in oil from 1500 degrees Fahr. and then drawn in oil for 15 minutes at 350 degrees Fahr., a piece was 652 Brinell before and after drawing and after drawing was file hard. No. 9 quenched the same way as No. 8 except taken out in the hardening range and drawn at once in oil for 15 minutes at 350 degrees Fahr., was 192 Brinell in the hardening range and was nonmagnetic. After drawing No. 9 was 652 Brinell and file hard.

No. 10 when hardened regularly in water from a temperature of 1440 degrees Fahr. and then drawn at 250 degrees Fahr in oil for 15 minutes was 683 Brinell before and after drawing and was file hard after drawing. No. 11 quenched the same as No. 10 except taken out in the hardening range and drawn at once to 250 degrees Fahr. in oil for 15 minutes was 321 Brinell in the hardening range and was magnetic. After drawing No. 11 was 683 Brinell and file hard.

Results of Hardening Range Tests

Test No. 1. Specimen ½-inch square. Quenched in oil from 1475 degrees Fahr. Removed from bath while in the hardening range.

Test No. 2. Specimen ½-inch square. Quenched in water from 1440 degrees Fahr. Removed from bath while in the hardening range.

Test No. 3. Specimen circular, 0.156-inch gage. Quenched in oil from 1500 degrees Fahr. Removed from bath while in the hardening range.

Test No.	Annealed Length inches	Annealed Brinell hardness	Hardening Range Length inches	Hardening Range Brinell hardness	Cold Length inches	Cold Brinell hardness
1	4.438	192	4.429	192	4.440	652
2	3.968	179	3.973	262	3.978	652
3	4.993	231	4.980	192	4.996	652

Test No. 4. Specimen quenched in oil from 1500 degrees Fahr. until cold, and then drawn at 400 degrees Fahr. in oil for 15 minutes.

Test No. 5. Specimen quenched in oil from 1500 degrees Fahr., but taken out in the hardening range and drawn at once at 400 degrees Fahr. in oil for 15 minutes.

	Test No. 4	Test No. 5
Brinell hardness after quenching	652	192 (nonmagnetic)
Brinell hardness after drawing	652	652
Filed	Slightly	Slightly
Brinell hardness after redrawing at 400 degrees Fahr. for 15 minutes	627	627
Filed	Easily	Easily

Test No. 6. Specimen ½-inch square. Quenched in water from 1440 degrees Fahr. until cold, and then drawn at 400 degrees Fahr. in oil for 15 minutes.

Test No. 7. Specimen ½-inch square. Quenched in water from 1440 degrees Fahr., but taken out in the hardening range and drawn at once at 400 degrees Fahr. in oil for 15 minutes.

Test No.	Annealed Length inches	Annealed Brinell hardness	Quenched Length inches	Quenched Brinell hardness	Drawn Length inches	Drawn Brinell hardness
6	4.146	179	4.159	683	4.155	627
7	4.171	179	....	302	4.176	627

Test No. 8. Specimen quenches in oil from 1500 degrees Fahr. until cold, and then drawn at 350 degrees Fahr. in oil for 15 minutes.

Test No. 9. Specimen quenched in oil from 1500 degrees Fahr. but taken out in the hardening range and drawn at once at 350 degrees Fahr. in oil for 15 minutes.

	Test No. 8	Test No. 9
Brinell hardness after quenching	652	192 (nonmagnetic)
Brinell hardness after drawing	652	652
Filed	Hard	Hard

Test No. 10. Specimen quenched in water from 1440 degrees Fahr. until cold, and then drawn at 250 degrees Fahr. in oil for 15 minutes.

Test No. 11. Specimen quenched in water from 1440 degrees Fahr. but taken out in the hardening range and drawn at once at 250 degrees Fahr. in oil for 15 minutes.

	Test No. 10	Test No. 11
Brinell hardness after quenching	683	321 (nonmagnetic)
Brinell hardness after drawing	683	683
Filed	Hard	Hard

Test No. 12. Specimen quenched in oil from 1500 degrees Fahr. but taken out in the hardening range. Afterwards drawn at 800 degrees Fahr.

Test No. 13. Specimen in oil from 1500 degrees Fahr., but taken out in the hardening range. Afterwards drawn at 800 degrees Fahr.

	Test No. 12		Test No. 13	
	Length inches	Width inches	Length inches	Width inches
Annealed	60,286	4,694	60,396	6,000
Hardening range	60,091	4,684	60,203	5,987
Cold	60,323	4,696	60,422	6,004
Drawn	60,087	4,690	60,294	6,000

Test No. 14. This specimen, 5.540 x 0.75 x 0.050 inches, was quenched from 1500 degrees Fahr in oil. It was removed from the oil while in the hardening range and proved to be nonmagnetic. Its changes in size, as shown in the following, are in the same proportion as a so-called oil-hardening steel.

	Length inches
Annealed	5.5400
Hardening range	5.5315
Cold	5.5465

By comparing Nos. 6 and 7 and Nos. 10 and 11 it will be seen readily that a drawing temperature of 400 degrees Fahr. was too high for this particular steel for the reason that the martensite was decomposed at this temperature and consequently the piece could be filed readily, whereas Nos. 10 and 11, which were drawn at 250 degrees Fahr., were file hard after drawing.

Comparing Nos. 4 and 5 and Nos. 8 and 9 it is seen that 400 degrees Fahr. is too high for the drawing of this steel for the same reason that applies to Nos. 6 and 7, whereas 350 degrees Fahr. leaves the pieces file hard after drawing.

It seems almost paradoxical that these steels exhibit in the hardening range a low .Brinell and at the same time are practically file hard and can be deformed readily. Similar observations have been made on a variety of other steels which harden solid in oil, such steels containing about 1.00 per cent tungsten; chrome and tungsten; chrome, vanadium and tungsten; chrome; and chrome and vanadium. Data is being prepared on high speed steel.

The foregoing tests indicate that all steels, and perhaps high speed steel, when quenched and hardened solid first shrink and then expand. The nonmagnetic properties of water hardening steels in the hardening range are difficult to determine because of the rapidity of quenching but by reference to test No. 14, it is noted that when a water hardening steel hardens solid in oil, it exhibits the characteristic hardening range properties of a regular oil hardened steel and vice versa. It can be shown that an oil hardening steel

like Nos. 1 or 3 when quenched in water have the characteristic properties of a water hardening steel. Therefore, it is logical to assume, and it may even be demonstrated that all steels whether oil or water hardening, which harden solid when quenched, are at some stage of the hardening range nonmagnetic.

Since the steels in this paper, of the oil hardening type and also No. 14, are nonmagnetic in the hardening range, and since it is the theory held by many that all steels above the Ac range contain gamma iron, and since it is well known that steels above the Ac range are nonmagnetic, it naturally follows that the steels in this report contain gamma iron in the hardening range and are therefore austenitic in that range.

Since in order to harden, a steel must pass through the Ar range, it follows that these steels have not passed through the Ar range when taken from the oil in the hardening range but the Ar has been suppressed to a temperature approximating 400 to 500 degrees Fahr. A further deduction is that in the hardening range austenite occupies a smaller volume and has a higher specific gravity than martensite.

This deduction as to the specific gravity of the microconsituents is based entirely on the observations of the change of volume of the steels as noted in these tests and is therefore only a tentative deduction. It may well be proved that these changes of volume are not alone due to the formation of the different microconstituents but also may be due to intermolecular change on account of change of temperature. The writer does not seek to propound theories in this paper but merely wishes to draw attention to certain observations. It is earnestly hoped that these observations may draw from other metallurgists more and clearer reports and deductions.

It would seem safe to say that the practical value of this investigation is that it indicates certain possibilities. It is perfectly apparent from the tests that when a steel which hardens solid is quenched it first contracts and then expands in the hardening range. Since this expansion begins and is most rapid at the thinnest section and in the region farthest from the center of the steel it naturally follows that any quenched steel such as punches, dies, cutters, etc., should be withdrawn from the quenching medium in the hardening range and placed at once in a medium sufficiently hot to permit the martensite to form slowly and completely and uniformly but not hot enough to start the decomposition of the martensite into troostite or sorbite.

It may be stated as a truth that a steel properly treated in the hardening range, providing of course that the steel is of the correct analysis and has been made right, will be less liable to rupture and will show a minimum of deformation.

Attention is called to photomicrographs, Figs. 1, 2, 3 and 4. Fig. 1 is No. 1 steel quenched in oil from 1475 degrees Fahr. until cold and then drawn 15 minutes in oil at 350 degrees Fahr. Fig. 2 is No. 1 steel quenched in oil from 1475 degrees Fahr., removed in the hardening range and drawn at once for 15 minutes in oil at 350 degrees Fahr. Fig. 3. is No. 2 steel quenched in water from 1440 degrees Fahr. until cold and then drawn in oil at 250 degrees Fahr. for 15 minutes. Fig. 4 is No. 2 steel quenched in water from 1440 degrees Fahr., removed in the hardening range and drawn at once in oil at 250 degrees Fahr. for 15 minutes.

Both Figs. 2 and 4 show a much more perfect martensitic structure than Figs. 1 and 3. It would be expected that Figs. 2 and 4 would be much tougher steels than Figs. 1 and 3 and with better cutting qualities. It seems

reasonable to suppose that a steel cooled slowly through the hardening range would be more completely martensitic whereas the same steel quenched regularly might have in its structure some trapped austenite.

It can be stated further that soft spots in oil hardening steels which harden solid can be detected in the hardening range with absolute certainty by

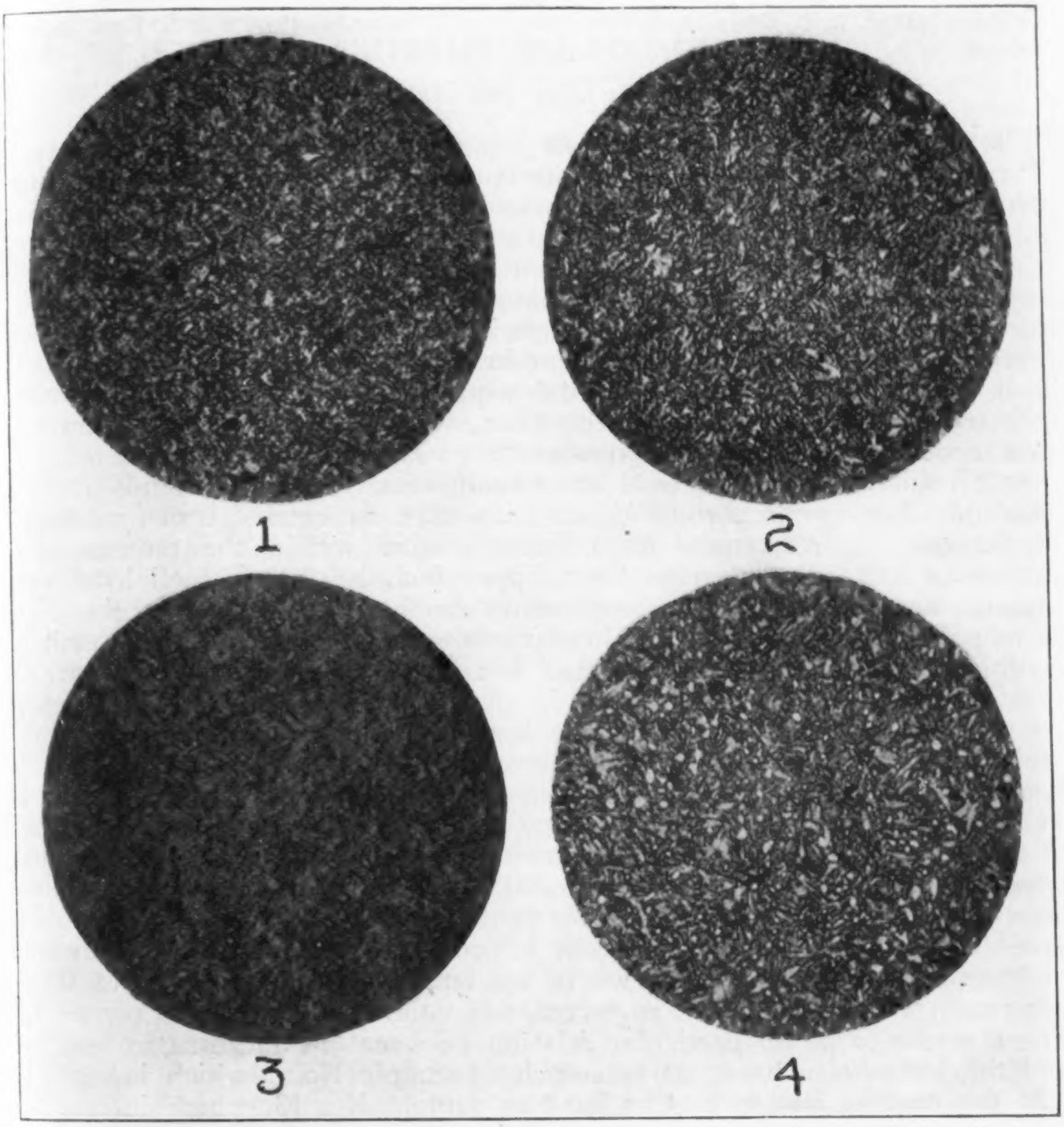

Fig. 1—No. 1 steel quenched in oil from 1475 degrees Fahr. until cold and then drawn 15 minutes in oil at 350 degrees Fahr. X 855. Fig. 2—No 1 steel quenched in oil from 1475 degrees Fahr., removed in the hardening range and drawn at once for 15 minutes in oil at 350 degrees Fahr. X 855. Fig. 3—No. 2 steel quenched in water from 1440 degrees Fahr. until cold and then drawn in oil at 250 degrees Fahr. for 15 minutes. X 855. Fig. 4—No. 2 steel quenched in water from 1440 degrees Fahr., removed in the hardening range and drawn at once in oil at 250 degrees Fahr. for 15 minutes. X 855

the use of a magnet. The writer has demonstrated this beyond a reasonable doubt. It should be strongly emphasized that a steel taken from the quenching bath in the hardening range should be placed at once in a medium of the proper temperature. Steels withdrawn in the hardening range are very liable to rupture if allowed to cool in the air. The reason is perfectly obvious.

Indeed, it seems almost a miracle that all quenched steels do not fly to

pieces and it can only be explained, at least to the writer's mind, by the fact that the Great Creator Himself gave the hardening power of steel for the use of mankind.

The author desires to give acknowledgement and thanks to W. L. Appel, assistant director of testing department, for his able and enthusiastic co-operation in the preparation of this paper.

DISCUSSION OF MR. CHAPIN'S PAPER

By Zay Jeffries

THIS work of Mr. Chapin fills an important gap in the history of steel treating. In the early days of the study of critical points and study of structure under the microscope, it was believed that the rapid cooling of steel from above its critical point did not greatly change the temperature of transformation but it was known that the resulting structures and physical properties were greatly changed by the rapid cooling through the critical range. A few years ago Portevin and Garvin[1] showed by thermal analysis that the constituent known as martensite, which is the hard constituent in steel produced by quenching, was in reality formed at a temperature near 300 degrees Cent., whereas the transformation on slow cooling takes place at a temperature near 700 degrees Cent.

Mr. Chapin now confirms the conclusions of Portevin and Garvin and adds the very important information that the rate of transformation of austenite to martensite is sufficiently slow within the temperature ranges of 200 to 300 degrees Cent. approximately, that Brinell hardness measurements and length measurements can be made on the steel while it is still austenite, after which martensite forms quickly with further cooling or more leisurely if the steel is allowed to remain at a temperature of 200-300 degrees Cent.

Mr. Chapin's results also make it possible to calculate more accurately the increase in volume when austenite changes to martensite than has heretofore been possible. Taking his tests Nos. 1, 2, 3, 12, 13, and 14, it is found that there is an average increase in length of 0.31 per cent of the martensite at room temperature as compared to austenite at a temperature which we will call about 200 degrees Cent. Inasmuch as the steel should contract about 0.25 per cent on cooling from about 200 degrees Cent. to room temperature, it is probable that the actual increase in length at the temperature where martensite is formed is about 0.55 per cent. This would mean an increase in volume of about 1.65 per cent. There seems to be no particular relation between the increase in length and the increase in hardness inasmuch as sample No. 1 which increased 0.24 per cent in length was as hard as sample No. 13, which increased 0.37 per cent in length.

Dr. Arne Westgren in Sweden and Mr. Bain and the writer in Cleveland, have shown definitely by means of X-ray crystal analysis that the crystal lattice of austenite is face centered cubic and that of ferrite, that is ordinary alpha iron, is body centered cubic. We have also shown that manganese steel which is also austenitic has a face centered cubic lattice whereas martensite has the same lattices as alpha iron. For the first time, therefore, we are sure that martensite is alpha iron, or at least that

1—Journal, Iron and Steel Institute, No. 1, 1919, p. 469.

The author, Zay Jeffries, is director of research, Aluminum Co. of America, Cleveland.

alpha iron is the principal constituent of martensite. This is consistent with the fact that the change of austenite to martensite is always accompanied by an increase in volume because the face centered cubic lattice of austenite represents close packing of the atoms, whereas the body centered lattice of ferrite is not a close packed lattice.

In *Chemical and Metallurgical Engineering* for June 15, 1921, R. S. Archer and the writer presented a paper entitled "The Slip Interference Theory of the Hardening of Metals" in which we put forth the proposition that martensite is composed of very fine grains of ferrite and is hard chiefly because of the fineness of the grain. The expansion when austenite changes to martensite is typical of the expansion which takes place when pure gamma iron changes to alpha iron. In steels we consider that the carbon is dissolved in the austenite as individual atoms of carbon. Ferrite does not dissolve any considerable quantity of carbon. Therefore, when austenite changes normally to its transformation constituents, the iron changes to the alpha form and the atoms of carbon combine with the proper proportion of iron to form the compound Fe_3 C. The formation of this compound is accompanied by a contraction and in a steel containing about 1 per cent carbon, the contraction due to the formation of cementite is about equal to the expansion due to the change of gamma iron to alpha iron, so that slowly cooled steels of this composition show no appreciable volume change at the critical temperature.

When steels of this composition are quenched, however, as shown more accurately in Mr. Chapin's paper than heretofore, the expansion takes place just as if the carbide had not formed simultaneously with the formation of martensite. Other considerations point to the same conclusion. If the carbide is allowed to form, contraction immediately sets in. Also the heat given off when a 1 per cent carbon steel changes from austenite to pearlite at a temperature of about 700 degrees Cent. is partly due to the transformation of gamma iron to alpha iron and partly to the formation of cementite. There is heat given off when austenite changes to martensite but it is not so much as when austenite changes to pearlite. When martensite is heated gently a further heat evolution goes on within the metal which presumably is the heat generated by the carbide formation. Another observation by Honda also points to the conclusion that the carbide has not formed in freshly formed martensite. Cementite itself has a magnetic transformation point at about 220 degrees Cent. This point is not observed on heating freshly formed martensite but after the martensite has been heated to 300 degrees Cent., the point is observed either on cooling or heating.

These and other considerations lead to the conclusions which Mr Archer and the writer came to in the paper above cited. The work reported by Mr. Chapin is in complete harmony with these ideas and in addition it gives us a better picture of the actual formation of martensite than has ever before been presented.

GHOST LINES AND GRAIN ELONGATIONS IN HOT ROLLED AND COLD DRAWN LOW CARBON STEEL WIRE

By N. B. Hoffman

TO SHOW the relation existing between ghost lines, bands, and elongated grain structures, as found in low carbon steel wire, is the purpose of this article. In considering a subject of this kind, we should first decide just what is a ghost line, a band, an elongated grain structure, and what metallurgical conditions lend themselves to their production and growth. Some metallurgists are prone to call all three of them ghost lines, while others would call them bands.

Technically speaking, it is generally interpreted that a ghost line in the metal, when under examination with the microscope, contains white bands or streaks of ferrite of various widths and lengths which are impregnated with abnormally large proportions of manganese sulphide and phosphorus. They may be brought about by several causes. Rosenhain says phosphorus is present in solid solution in the ferrite of the ingot, but in the form of solid solution cores, so that the phosphorus content of each crystal increases from its center to its periphery. When rolled out these crystal cores assume the form of elongated masses, and although the ferrite itself undergoes complete recrystallization possibly repeatedly, there is nothing to cause the phosphorus to migrate except the process of diffusion, which is particularly slow in that case. The result is that in the finished material the phosphorus rich ferrite still remains in long bands or streaks and these bands pass indifferently through numbers of individual crystals, indeed, an individual crystal may be partly within and partly outside of the bands. The growing ferrite crystal has simply used the material it found at hand whether rich in phosphorus or not.

Another claim is that ghost lines are formed in rolling or forging through the crystallizing of ferrite around strings of enclosures which are elongated in the direction of rolling. Particularly is this condition found in rolling at high temperatures. All steel contains a certain amount of sonims, or solid nonmetallic impurities, and when these amounts are small, finely divided and uniformly distributed throughout the metal, they should not be detrimental to the efficiency of the steel, but when the sonims are segregated and elongated as found in ghost lines, they produce points of weakness.

More or less confliction of opinion exists concerning bands. The author finds most authorities use the word band when referring to an elongated line of ferrite, which is simply another way of referring to a ghost line. Elongated grain structures as caused by cold work either in drawing or cold rolling, can be restored by annealing and you do not have the inclusion of nonmetallics. This condition is confined principally to low carbon wire steels having a carbon content under 0.20 per cent.

When a steel wire is reduced in area by drawing through a draw plate, the grain structure is elongated in the direction of drafting with each successive draw until a point is reached where the grains have been elongated to their limit of ductility and break due to brittleness. To overcome this condition the wire is given what is known as a process anneal at various stages during the reduction in area. This annealing process is usually

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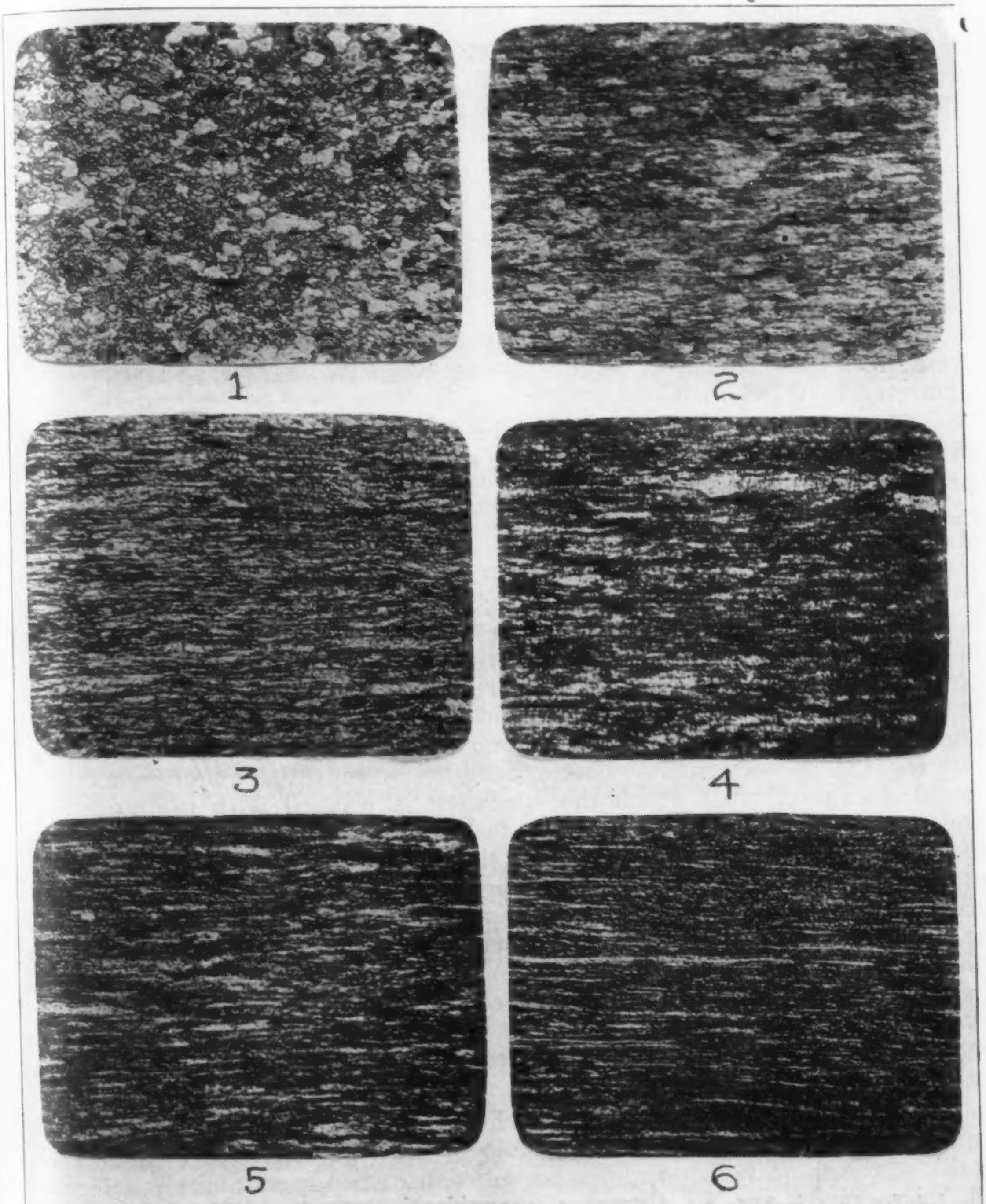
A paper presented at the Indianapolis Convention. The author, N. B. Hoffman, is chemist and metallurgist, Colonial Steel Co., Pittsburgh.

accomplished by heating the wire to between 1200 to 1280 degrees Fahr. and quenching the coil in water at a temperature of 65 degrees Fahr. It might also be said that in the excessive reduction of area without an anneal we invite another hazard, which of course has no direct bearing



Grain structures of hot rolled low carbon open-hearth steel wire during rolling operations. Fig. 1—Grain structure of 0.312-inch diameter steel rod following anneal at 1280 degrees Fahr. X 75. Fig. 2—Same wire after one pass and reduced to 0.251 inches. X 75. Fig. 3—Same wire after two passes and reduced to 0.197 inches. X 75. Fig. 4—Same wire after three passes and reduced to 0.175 inches. X 75. Fig. 5—Same wire after four passes and reduced to 0.148 inches. X 100. Fig. 6—Same wire after six passes and reduced to 0.108 inches. X 75.

on elongated grain structures. That is cupping and by it we mean a cupped shaped fracture in the center of the wire. This condition is caused by the center of the wire being harder than the surface and when it is drawn through the die, the surface flows faster than the center, thereby causing an uneven strain on its internal structure, finally producing the cupped shape internal fracture.

In analyzing the three structures, two types of steel were used, one a high grade basic open hearth and the other a basic bessemer. The analysis of each type is as follows:

Open Hearth	Per cent	Bessemer	Per cent
Carbon	0.19	Carbon	0.13
Manganese	0.21	Manganese	0.43
Phosphorus	0.010	Phosphorus	0.082
Sulphur	0.032	Sulphur	0.047
Silicon	0.09	Silicon	0.11

The basic open-hearth steel was hot rolled to 0.312 inch after which it was cold drawn by the usual process. The bessemer steel was hot rolled to 0.207 inch, after which it was given two draws and reduced in diameter to 0.148 inch.

Ghosts rich in phosphorus may be revealed by several methods. One of the more important is by the use of Stead's copper reagent, which is prepared as follows:

Cupric chloride	10 grams
Magnesium chloride	40 grams
Hydrochloric acid	20 cubic centimeters
Ethyl alcohol to make up to	1000 cubic centimeters

The above salts are dissolved in water to saturation and the whole made up to 1000 cubic centimeters with ethyl alcohol. The specimen is covered with a thin layer of the reagent and is never immersed in a bath of the liquid. The layer of liquid after remaining on the surface for one minute, is shaken off and a second layer dropped on the surface and left for the same period. This procedure is repeated as often as it is found desirable, after which the specimen is washed with boiling water and then with alcohol. The sample is heated enough by the water to remove the last traces of alcohol. If the reagent is applied in successive portions and the difference in the proportion of phosphorus be slight, the copper invariably precipitates on the purer portions first; but on repeated applications the copper gradually deposits also on the parts richer in phosphorus, and after many applications of the reagent the whole surface including the phosphorized parts, becomes coated with copper. However, if the phosphorus is very much concentrated in one or more parts, these remain perfectly bright and free from copper even after 10 applications of the reagent.

In showing micrographs, the author has used the center of the wire and a section longitudinal to the rolling or drawing axis of the same. All etching was done with an alcoholic solution of 5 per cent nitric acid and all micrographs are 75 diameter magnifications unless otherwise noted. We will first consider a basic open-hearth drawn wire showing the gradual breaking up or elongation of the grain structure after each pass.

The wire was hot rolled to 0.312-inch rod after which the coil was heated to 1280 degrees Fahr. and quenched in water at 65 degrees Fahr. This treatment would give a semi or process anneal, and is the method

generally used for this class of work. Fig. 1 shows the grain structure of the 0.312-inch rod after it has received a water anneal at 1280 degrees Fahr. Fig. 2 was taken after the preceding rod had received one pass and reduced in diameter from 0.312 to 0.251 inch. It shows a gradual breaking up of the grain structure. Fig. 3 was taken after the wire had

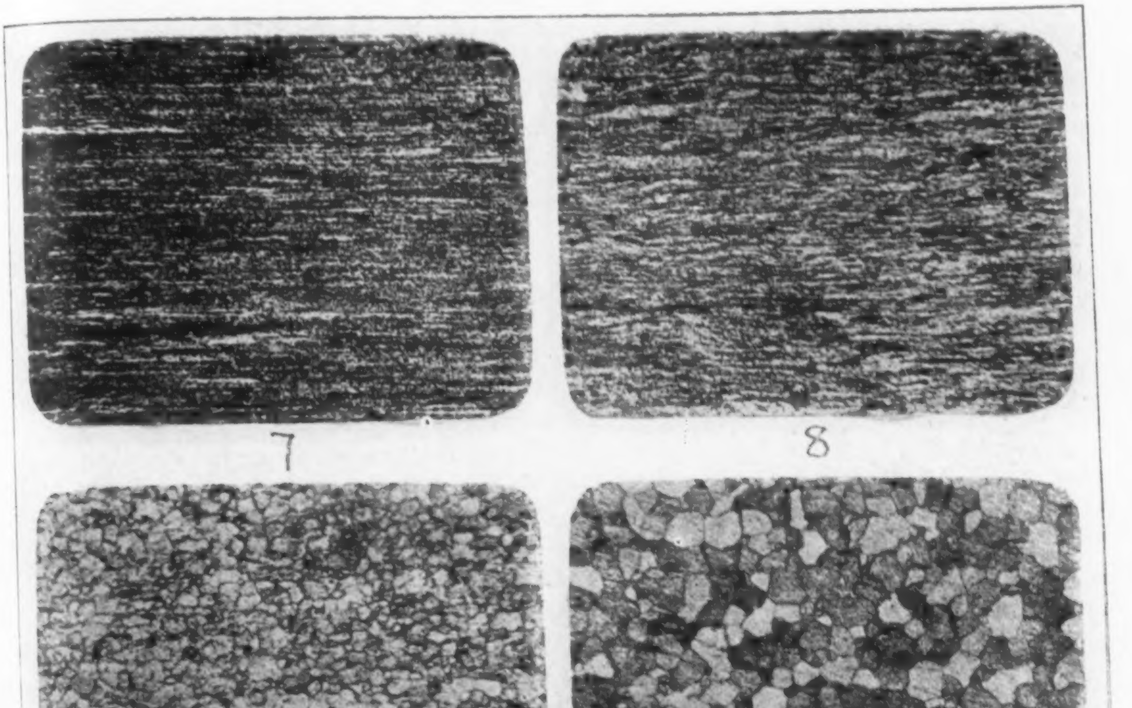


Fig. 7—Same wire as in Fig. 1 after 10 passes and reduced to 0.070 inch. X 75. Fig. 8—Structure of open-hearth steel wire after two draws, being reduced from 0.312 to 0.197 inch. X 75. Fig. 9—A section of the wire drawn to 0.197 inch and heated to 1350 degrees Fahr. X 75. Fig. 10—Same as Fig. 9 but heated to 1600 degrees Fahr. and cooled slowly. X 75. Fig. 11—Same as Fig. 10 but X 330. Fig. 12—A specimen reduced from 0.312 to 0.108 inch in six draws without heat treatment. X 75.

received two passes, and had been reduced in diameter from 0.251 to 0.197 inch and shows the grain structure beginning to break up and elongate in the direction of drawing.

Fig. 4 was taken after the wire had received three passes, and had been reduced in diameter from 0.197 to 0.175 inch and shows the grain

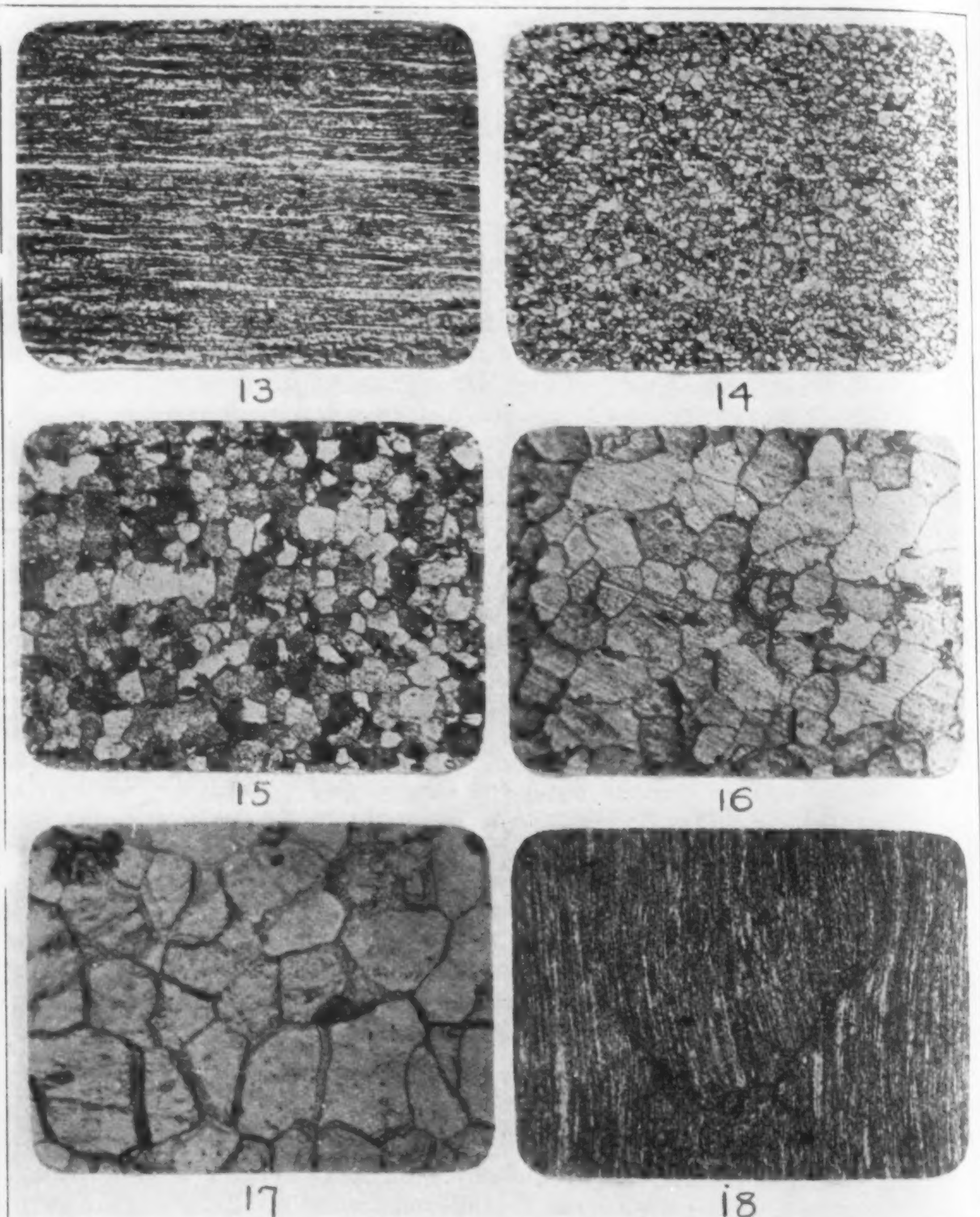


Fig. 13—Same specimen as Fig. 12 but X 150. Fig. 14—Same as Fig. 12 but heated to 1350 degrees Fahr. and cooled slowly. X 75. Fig. 15—Fig. 14 heated to 1600 degrees Fahr. and cooled slowly. X 75. Fig. 16—Same as Fig. 15 but X 150. Fig. 17—Same as Fig. 15 but X 330. Fig. 18—An overdrawn specimen showing the characteristic cup fracture. X 75.

structure continuing to break up. Fig. 5 was taken after the wire had received four passes, and had been reduced in diameter from 0.175 to 0.148 inch. In this we see the grain structure being still further elongated. Fig. 6 was taken after the wire had received six passes and had been reduced in diameter from 0.148 to 0.108 inch. In this we see the grain structure so badly elongated as to indicate ghosts. Fig. 7 was taken after the wire had received 10 passes and had been reduced in diameter from 0.108 to 0.070 inch. In this micrograph we find the grain structure very badly elongated.

We will next take two of the drawn samples exhibiting the elongated grain structures which are often confused as ghost lines, anneal them and note the restoration of grain structure and the absence of any impregnated nonmetallic inclusions. Fig. 8 is a section of wire which has had two draws, being reduced in diameter from 0.312 to 0.197 inch. Fig. 9 is a section of the wire which has been drawn to 0.197 inch and heated to 1350 degrees Fahr., and even at this low temperature we find the elongated grain structure practically broken up, but of course the heat has not been carried high enough to have any real grain growth. Fig. 10 shows the preceding specimen heated to 1600 degrees Fahr. and cooled slowly. In this we see a good recrystallized grain structure containing no impregnated impurities. Fig. 11 is a view of the preceding specimen which had been heated to 1600 degrees Fahr. and magnified at 330 diameters.

Fig. 12 is a specimen that has been reduced in diameter from 0.312 to 0.108 inch in six draws without any heat treatment. It shows a badly elongated grain structure. Fig. 13 is from the same specimen as the preceding micrograph, but magnified at 150 diameters, and shows plainly what is often called ghost lines. Fig. 14 is the same specimen which has been reduced in diameter from 0.312 to 0.108, and which has been heated to 1350 degrees Fahr. and cooled slowly. In it we again see the elongated grains rearranging themselves to form a new structure. Fig. 15 shows the preceding specimen heated to 1600 degrees Fahr. and cooled slowly. In this we see a good crystallized grain structure containing no impregnated impurities. Fig. 16 is the same specimen as shown in the preceding micrograph magnified at 150 diameters. Fig. 17 is the same specimen as shown in the preceding micrograph magnified at 330 diameters. Fig. 18 is from a specimen of wire which had been overdrawn, and exhibits the characteristic cup fracture.

We will next consider a sample of hot rolled bessemer steel, the micrographs show these samples to contain well defined ghost lines. Fig. 19 shows a section of wire after it was hot rolled to 0.207-inch and drawn to 0.148-inch in two draws without any heat treatment, and shows three distinct bands which after heat treatment are shown to be true ghost lines. Fig. 20 is the same specimen as shown in the preceding micrograph, except that it has been heated to 1350 degrees Fahr. and allowed to cool slowly. In it we see the bands persisting but with the ferrite beginning to recrystallize. Comparing this micrograph with Fig. 14, in the elongated grain structure series shows the persistence of the bands in the latter instance. Fig. 21 is from the same specimen as the preceding micrograph except that it has been heated to 1600 degrees Fahr. and cooled slowly. Fig. 22 is the same specimen as in the preceding micrograph except that it has been heated to 1700 degrees Fahr. and allowed to cool slowly. In it we see the grain structure entirely broken

up, but with the lines of inclusions which are high in phosphorus intact. It is also noted that they extend directly through the grains and do not follow the grain boundaries. Fig. 23 is another view of the preceding specimen, magnified at 150 diameters to show the line of inclusions high in phosphorus running directly through the grains. Fig. 24 is a view of the preceding specimen magnified at 330 diameters, to show the en-

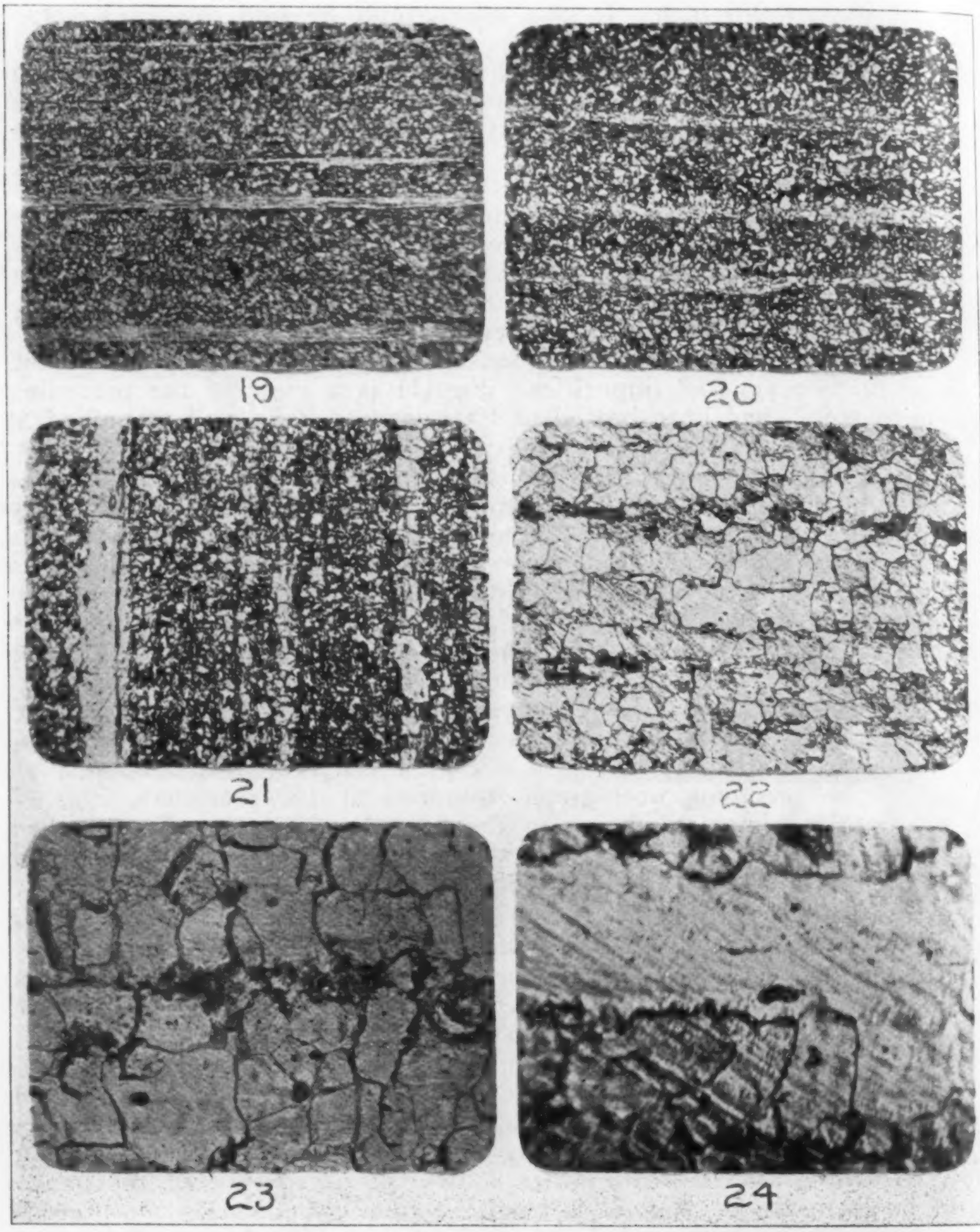
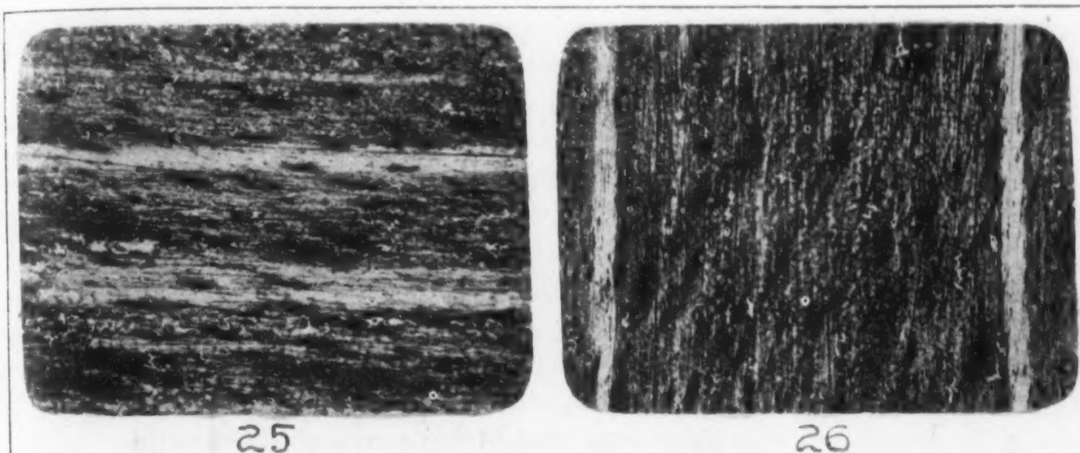


Fig. 19—Structure of a bessemer steel wire hot rolled to 0.207-inch diameter and drawn to 0.148 inches in two draws without heat treatment. X 75. Fig. 20—Same as Fig. 19 but heated to 1350 degrees Fahr. and cooled slowly. X 75. Fig. 21—Same as Fig. 19 but heated to 1600 degrees Fahr. and cooled slowly. X 75. Fig. 22—Same as Fig. 19 but heated to 1700 degrees Fahr. and cooled slowly. X 75. Fig. 23—Same as Fig. 22 but X 150. Fig. 24—Same as Fig. 22 but X 330.

larged grain growth due to the presence of phosphorus in solid solution in the grain. It will be noted that one grain covers practically the entire micrograph.

A specimen of bessemer wire as drawn and shown in Fig. 19, was heated to 1600 degrees Fahr. and cooled slowly, then polished and etched with Steads copper reagent, as previously described. Copper is precipitated on the parts low in phosphorus and not on the areas high in phosphorus, and in the following micrographs, Figs. 25 and 26, which represent the above copper treated specimen, is noted the distinct heavy white lines or ghosts high in phosphorus.

In conclusion the author might say that in examining steels low in phosphorus and sulphur, he has found but few ghost lines, while in



Figs. 25 and 26—Specimen shown in Fig. 19 heated to 1600 degrees Fahr. and cooled slowly, then polished and etched with Stead's copper reagent. X 75. Heavy white lines represent ghosts high in phosphorus.

steels high in sulphur and phosphorus, they have often been very prolific due to the presence of much material necessary for their growth. We all have our pet ideas as to the most fertile conditions for the growth of ghost lines, but personally the author believes there are as many formed by very hot rolling as produced by any other cause. He also believes that hot rolling has as much to do with it as the freezing of dendritic properties in the ingots.

Discussion of Mr. Hoffman's Paper

MEMBER: How many passes were made of that steel wire before you got your first fracture? You say you reduced it from 0.312 to 0.079 inches?

MR. HOFFMAN: You mean, how many passes were made on the wire?

MEMBER: Yes, before it got so brittle it broke in the operation.

MR. HOFFMAN: Ten. I believe you are as familiar with the ordinary practice as I am. If I am not mistaken, five drafts are considered the maximum, although most people do not take over three.

MEMBER: You annealed the open-hearth bar after hot rolling before you started drawing?

MR. HOFFMAN: Yes.

MR. FOLEY: What is the effect of that striation of which you mention on the quality of wire?

MR. HOFFMAN: Brittleness.

MR. FOLEY: Brittle wire with long stringers in it?

MR. HOFFMAN: Absolutely. Where you have an elongated section such as shown in Fig. 23, with a line of sonims running directly through the grain structure, the metal body is naturally weakened.

MR. FOLEY: The bands themselves are the cause of brittleness?

MR. HOFFMAN: The phosphides and sulphides are really the cause of brittleness, naturally, but a wire overdrawn, we will say, is bound to be brittle, but that same wire will get brittle much quicker if it were full of sonims and ghost lines.

MR. FOLEY: You find when you have the long bands or ghosts that it will break quicker than otherwise?

MR. HOFFMAN: Yes and you will be surprised how numerous they are in some wires.

MR. FOLEY: In the case of the bessemer wire, did you just draw the two passes and quit?

MR. HOFFMAN: Yes.

MEMBER: You have no comparison?

MR. HOFFMAN: No comparison. I did not draw it down to the same number of passes for the reason that my only thought was to show the comparison between elongated grain structure and a ghost line.

MR. FOLEY: Wrought iron would be particularly brittle.

MR. HOFFMAN: Wrought iron is permeated with elongated slag inclusions, and as hot rolled it is not brittle. but were it reduced by drawing through a draw plate as in a wire, undoubtedly it would be weak.

MR. SCOTT: The carbon point in both wires was very low?

MR. HOFFMAN: Very low. Ten.

MR. SCOTT: Which structure did you use? You had two or three various grain sizes. You used the smallest?

MR. HOFFMAN: I dont quite get your question. I used the various grain sizes obtained through the different heat treatments.

MR. SCOTT: I wondered what your finished product was.

MR. HOFFMAN: The finished product, we will say, really should be around the third draw, after the third or fourth draw, which was shown.

MR. SCOTT: That was annealed at 1350 degrees Fahr.?

MR. HOFFMAN: You would not have a finished product in any annealed condition.

MR. SCOTT: I did not think so.

MR. HOFFMAN: No, the micrograph in Fig. 5 will illustrate that point. The idea of the process of annealing, of course, is to make the metal malleable in order that it may be worked readily. I wouldn't carry a wire any further than the reduction shown. If you did I would say it would be liable to be dangerous. That has had four draws, rather

heavy ones. When you say so many draws and so many drafts you must assume reduction at the same time.

MR. FOLEY: Why do you say that hot working would be responsible for this rather than that they have their hardness in the dendritic structure? How could hot working cause it?

MR. HOFFMAN: It is claimed in hot working the nonmetallics flow together and the ferrite crystallizes around the sonims, just the same as it would in the ingot. My assertion has been caused more through observation. I have noticed in numerous cases where some wires of the same batch of metal would be hot worked and the others cold worked, the hot worked material invariably would be worse than the cold worked metal.

MR. FOLEY: I know you have used agents in trying to get rid of that same banded structure, used a high temperature for a long time for the purpose of diffusing the phosphite and sulphite. Is it safe to do it at a high temperature?

MR. HOFFMAN: I used a high temperature to crystallize the ferrite.

MR. FOLEY: The high temperature promoted a diffusion?

MR. HOFFMAN: No. Merely recrystallizes the ferrite.

MR. FOLEY: I remember Charpy did the same thing with a high temperature. He succeeded in diffusing phosphite and sulphite and in breaking up the structure.

MR. HOFFMAN: Yes, by soaking at a high heat for a number of days, but that procedure would be impossible as a commercial proposition.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

CARBON CONTENT CORRECTED

IN THE discussion "Cyanide Data Seems Confusing" by Stanley P. Rockwell, which appeared on page 442 of the February TRANSACTIONS, the carbon contents mentioned in the first paragraph were found to be in error. When corrected the second and third lines should read "Various investigations have analyzed the case formed in cyanide hardening and found that the carbon content varies from 0.3 to 0.6 per cent."

EFFICIENCY OF DIFFERENT MIXTURES FOR CYANIDE HARDENING AND THE ROLE OF NITROGEN IN THE PROCESS

THE following comments are relevant to the constructive criticisms which appeared on page 443 of the February TRANSACTIONS. With reference to Mr. Brophy's remarks, the author is pleased to reply thereto in the order of their presentation:

Depth of Case. The depth of case, as recorded in the subject paper, "is ascertained by measuring the distance from the outer edge of the specimen to the center of the second zone." Mr. Brophy writes that he measured the depth of penetration by "estimating the distance from the surface to the innermost needle." Such procedure, in my opinion, is uncertain. Nitrogen needles possess a roving tendency. They may be found in cyanided specimens at depths appreciably below the accepted case. The writer's paper purports to the depth of case, whereas Mr. Brophy's criticism deals with the depth of nitrogen penetration. They are distinct.

Carburizing Action. The writer's use of the word carburizing is justified. Attention is also called to the fact that Mr. Brophy uses the word in a similar sense namely: "When Na_2CO_3 is melted it is a well known fact that CO_2 is liberated, also that NaCN is an active reducing agent. Therefore, is it not possible that CO_2 is reduced to CO with the formation of NaOCN, and the steel carburized by CO?" Carburizing is defined as the introduction of carbon into steel or iron while the metal is below the melting temperature. Mr. Brophy's experiments confirm the writer's use of the word carburizing. His original specimen contained no carbon. An analysis subsequent to the cyaniding operation revealed 0.33 per cent carbon.

It is admitted that nitrogen hardens steel, but it is equally true that carbon functions in a similar manner. The hardness of the cyanide case, is in the writer's opinion, the result of the combined influences of nitrogen and carbon.

Sodium Carbonate. Mr. Brophy also questions the accuracy of the statement that sodium carbonate is inert. Attention is directed to the Curve *B*

in the subject paper page 298, January TRANSACTIONS, which represents the performance of a bath containing 76 per cent sodium cyanide, and 22.5 per cent sodium chloride. Note the absence of sodium carbonate. Notwithstanding, carburization has taken place. The curve practically parallels the performance of the bath which contains 54 per cent sodium carbonate. Therefore, by a process of elimination, the writer re-affirms his statement that sodium carbonate is inert.

Flavite. Mr. Brophy further states that "the term 'Flavite' given to this patch constituent by Mr. Hillman, is a new one, not having been used in previous publications." The word was used by J. Kirner in his publication which records his remarkable observations on the case hardening of steel, especially in regard to the effect of nitrogen; "Metallurgie" 1911, Vol. 8, page 72. In the 1915 edition of Giolitti's admirable work on the "Cementation of Iron and Steel," the word appears on page 139 in precisely the same role as that used by the author.

V. E. HILLMAN, Metallurgist,
Crompton & Knowles Loom Works,
Worcester, Mass.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. What is needle bar stock?

QUESTION NO. 6. Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?

QUESTION NO. 7. May tools be heat treated properly in a furnace in which copper is present?

QUESTION NO. 8. What is the effect of high and low silicon in tool steel?

QUESTION NO. 9. In carbonizing does not the carbon increase slightly even in the core section?

QUESTION NO. 10. What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?

QUESTION NO. 11. Has high speed steel ever been carbonized and if so what were the results?

QUESTION NO. 12. How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?

QUESTION NO. 13. A swaging die for tubing receives 3600 blows per minute. It has been found that a scleroscope hardness of about 95 is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?

QUESTION NO. 14. What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.

QUESTION NO. 17. For some time past we have been water quenching steel castings in order to improve their physical properties. These castings are mostly shrouded pinions and plain rollers, weighing from 150 to 500 pounds each. These pieces would be immersed in the water bath for a short period of time, usually from one to two minutes and then withdrawn and

allowed to cool in the air. Our results have been satisfactory but we feel that we can improve this method somewhat by a slight modification in the treatment. In order to relieve cooling strains, one suggestion is that we provide a tank filled with infusorial earth in which the castings would be placed in order that cooling might be slow and uniform. Another suggestion is that instead of using a plain water bath, we introduce sodium hydrate in order that the quenching may not be quite so severe. We would like to know which of the above plans would be the better or if there is any other better plan which could be suggested. We do not care to use oil because of its expense.

NOTE. Rollers may break in the flange a month or more after above treatment. Loss at present is 2 per cent. Pinions, after above treatment, are drawn in furnace to 1200 degrees Fahr. for toughness. If drawn shortly after quenching there is no trouble, but this is not always practicable when working day turn only. If allowed to stand in air after quenching, cracking may result, hence the suggestion for covering with infusorial earth or ashes. We have had only one batch to show cracks.

QUESTION NO. 18. What is the relationship between Brinell and Scleroscope hardness?

ANSWER. By C. F. Green, Henry Souther Engineering Co., Hartford, Conn. Robert R. Abbott has determined the relation between Brinell and scleroscope hardness probably as definitely as it is possible to do so in his contribution to the *Proceedings* of the American Society for Testing Materials, 1915, Vol. XV, under the title "The Relation Between Maximum Strength, Brinell Hardness and Scleroscope Hardness in Treated and Untreated Alloy and Plain Steels." His tests show that the relationship varies in different grades of steel, and a table of equations for converting from one scale to the other is given for the more common kinds:

Kind of Steel	Equation
Carbon steel	Brinell equals 5.6 scleroscope plus 14
Nickel steel	Brinell equals 5.0 scleroscope plus 48
Chrome-vanadium steel	Brinell equals 5.5 scleroscope plus 27
Low chrome-nickel steel	Brinell equals 5.4 scleroscope plus 33
High chrome-nickel steel	Brinell equals 4.8 scleroscope plus 58
All steels grouped together	Brinell equals 5.5 scleroscope plus 28

QUESTION NO. 19. What is the shortest time in which malleable castings can be annealed to produce the best malleable qualities?

ANSWER. By H. A. Schwartz, manager of research, National Malleable Castings Co., Cleveland. A strictly correct reply would probably be infinity since, speaking broadly, every means of accelerating graphitization is detrimental to the ductility of the product. A strictly logical conclusion thus would indicate that, the slower the process, the better the product, hence the best product can be made only in infinite time.

Graphitization proceeds more rapidly and less completely the higher the temperature. Its commercial execution is accomplished by holding the metal for a time at a temperature well above A_1 and then cooling in such a manner that the metal shall be at or near A_1 for a sufficient time to complete the reaction.

Time will be saved by executing the preliminary treatment at the highest practicable temperature. However, the higher temperature the coarser the temper carbon granules and the less the strength and ductility, consequently

there is a limit to the time to be saved by raising the initial temperature. Commercial opinion varies as to the highest safe temperature. Some manufacturers feel it unsafe to go above 1500 degrees Fahr.; others go as high as 1850 degrees Fahr. The former makes for quality, the latter for speed. A temperature of 1600 or 1625 degrees Fahr. is perhaps a conservative middle course.

Commercial practice varies with respect to the completion of the reaction. Some metallurgists cool slowly through the critical range; others feel it better to maintain a constant temperature just below A_1 for some time. The latter course, no doubt, saves time but requires very accurate control to avoid passing above A_1 by accident.

Graphitization can be accelerated by an increase in carbon or silicon, both of which deteriorate the quality of the metal when present in too large an amount. Here again speed is had at a sacrifice of quality.

In the early days, using carbon and silicon in amounts now considered excessive, it was very common to occupy 7 days for the annealing cycle. The recent improvements in malleable castings were accomplished in part by reductions in carbon and occasionally silicon and by greater annealing precautions. The time for annealing has thus risen for two reasons.

The writer has frequently annealed metal in small commercial furnaces in 3½ to 4 days. The metal was never of superior quality and frequently very unsatisfactory and this attempt to hasten deliveries was definitely abandoned.

The design of heating furnace also affects the answer since uniform rapid heating is difficult to attain in large furnaces; but such furnaces are economical of fuel and space.

Under commercial conditions and on an operating scale, the writer would regard with suspicion metal annealed in less than 7 days and would not regard 10 or 11 days as excessive.

Where particular importance is attached to ductility and to machineability, without sacrifice of strength; still longer times may be called for. A single piece, of inferior quality, could no doubt be produced experimentally in around 50 or 60 hours.

QUESTION NO. 20. What are the causes of warping in the heating and cooling of steel?

QUESTION NO. 21. In answering Question No. 3, which appeared in the January issue of TRANSACTIONS, *C. Craine, Mattison Machine Works, Rockford, Ill., refers to the fact that cast iron gage bases were treated at temperature from 600 to 900 degrees Fahr. for a period of 12 to 18 hours, and were allowed to cool in the furnace, the theory being that this treatment obviated the necessity for the ageing of the castings. What effect, if any, would have been produced had the castings been heated to a very much higher temperature, say 1600 degrees Fahr.? In view of the fact that certain of the castings referred to had to be twice re-treated in a similar manner for 12 to 24 hours, before overcoming all effects of warpage, the value of the treatment seems doubtful. What assurance is there that some of the castings which were treated but once, ought not to have been treated twice, or even three times?*

ANSWER. By H. A. Schwartz, manager of research, National Malleable Castings Co., Cleveland. Any casting develops internal stresses due to

unequal cooling and retains its final shape due to a balance between opposing internal stresses. On machining off stresses material, the equilibrium is disturbed and the casting warps. Ageing, heating, vibration or the removal of metal with light cuts on opposite sides all serve as a means of slowly relieving internal stresses and hence of preventing warping on subsequent machining. It would seem that to be effective as an eliminator of casting strains, the temperature reached in heat treating must be sufficiently high to cause a distinct increase in ductility of the iron. Such an increase is not observed until the metal is heated above 900 degrees Fahr., but the increase in softness with increasing temperature above 900 degrees Fahr. is very rapid. Any temperature above 1400 degrees Fahr. if maintained sufficiently long will cause a resolution of the graphite with possible increase of hardness unless cooling is very slow. At temperatures as high as 1600 degrees Fahr. the metal, if it contains graphite, must be protected from oxygen, or carbon dioxide, else these gases will oxidize carbon, penetrate into the metal first where the graphite was and later along the grain boundaries, oxidize the metal and produce a "rotten" product. In any event the cooling of the metal must be uniform throughout and quite slow.

ANSWER. By C. R. Crain, Mattison Machine Works, Rockford, Ill. It is evident that I have been misunderstood. First let me explain that the treatment in question was not adopted in preference to the "time and weather" method, but as an emergency measure to hasten the conditioning of the castings. The method used, while not to be recommended as standard practice, produced results for us that exceeded our expectations and enabled us to cut the time element considerably.

To carry the castings to a high temperature than 900 degrees Fahr. resulted in a perceptible softening as well as increase in volume. The size and shape of piece to be treated was the deciding factor as to the number of treatments. Small pieces that were not too delicate seldom required more than one treatment. Larger castings of delicate shape were first treated, then rough machined, then reheated and finished. During rough machining operations stresses are usually set up but can be relieved by a second treatment which seldom need be repeated. Close attention and good judgment will be necessary to insure success.

QUESTION NO. 22. Can ghost lines be eliminated by heat treatment?

NOTE. A difference of opinion exists on this subject as shown by the four brief answers submitted with the question. N. B. Hoffman says: Ghost lines can not be broken. The carbon can be recrystallized but the nonmetallics remain. W. J. Merten says: Ghost lines can be eliminated by heating to a very high temperature and cooling to the critical point rapidly. Then heat treat from this point. A. M. Cox says: Ghost lines can be prevented from forming. W. B. Crowe says: Ghost lines can not be eliminated but may be modified.

QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree that a piece of the same composition will if first subjected to forging?

QUESTION NO. 24. What methods can be suggested for brazing high speed sheet steel strips together, preferably during the hardening operation? A spelter of copper, tin, aluminum and borax finely pulverized seems to interfere with the proper hardening. The portion of the tool brazed must maintain a keen edge and have good red hardness.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

EFFECTS OF QUALITY OF STEEL ON CASE CARBURIZING RESULTS. By H. K. McQuaid and E. W. Ehn. Presented at the February meeting of the American Institute of Mining and Metallurgical Engineers.

The investigation was instituted as a result of occasional irregularities encountered in the hardening of carbonized roller bearings. Careful study brought out the fact that the defective pieces could be picked out with the aid of the microscope before hardening. Open-hearth steel invariably proved to be the offender, electric steel giving no trouble. Chemical analysis revealed nothing. The trouble seemed to be due to instability of the pearlite in the hyper-eutectoid region. The trouble was finally traced to the steel process, oxidized or overheated lots always giving rise to trouble.

MAKING A CASE HARDENED CRANKSHAFT. Anonymous, *American Machinist,* Vol. 56, Page 72.

The Franklin Motor Co. is at present carbonizing its crankshafts. The shafts are carbonized 24 hours at 1600 to 1700 degrees Fahr., cooled in the box and reheated for quenching to 1450 degrees Fahr.

CARBURIZING MATERIALS. By H. B. Knowlton, *Forging and Heat Treating,* Vol. 7, Page 590.

The various forms of carburizing are briefly discussed. Wood charcoal, leather, bone, coal and energized carbonizers are taken up in some detail. The results of some experiments in carbonizing are presented along with photomicrographs.

SPECIFICATIONS WHICH DON'T SPECIFY. By C. E. Carpenter, *Forging and Heat Treating,* Vol. 7, Page 587.

Attention is called to the fact that specifications for many technical materials do not insure that the buyer will get the best. It is suggested that specifications for case hardening compounds would as yet prove very unsatisfactory.

ELECTRIC STEEL AND IRON

THE STATUS OF THE ELECTRIC STEEL INDUSTRY. By E. F. Cone, *Iron Age,* Vol. 109, Page 85.

There are at present 388 electric melting furnaces in this country, 33 being installed last year. The sales figures of the various makes of furnaces are given together with information on their location.

MANGANESE STEEL MADE IN THE ELECTRIC FURNACE. By L. J. Barton, *Iron Age,* Vol. 109, Page 4.

Until very recently manganese steel was made in the converter. Electric manganese steel has proven much superior to converter-made stock. Directions for melting practice are given. Manganese steel ordinarily contains 11 to 13 per cent manganese and 1.10 to 1.30 per cent carbon. The steel as cast is very brittle, but after a heat treatment consisting of quenching the steel from 1800 degrees Fahr., great toughness is obtained.

THE MANUFACTURE OF CHROMIUM BALL BEARING STEEL IN THE HEROULT FURNACE. By F. T. Sisco, *Chemical and Metallurgical Engineering,* Vol. 26, Page 71.

From the results of five years experience in melting high carbon, high-chrome steel the best procedure has been worked out and is presented in this article. Methods of detecting hair-line seams are given.

ELECTROLYTIC IRON A COMMERCIAL PRODUCT. By Bradley Stoughton, *Iron Age*, Vol. 109, Page 32.

Two electrolytic iron plants are at present in operation, one at Hawthorne, Ill., and one at Grenoble, France. The properties of electrolytic iron are such as to make it very useful for any severe drawing or stamping operations. A great future is predicted for its use. Curves and data giving the tensile and anticorrosive properties are given.

MACHINING PROBLEMS

CUTTING FLUIDS. By E. C. Bingham, Bureau of Standards, Technologic Paper No. 204.

The function of the fluids used in cutting operations were studied in detail and the various fluids commonly used such as lard oil, mineral oil, soap solution, etc., investigated. As a result of the studies, recommendations are made as to the proper use of the various fluids investigated.

METALLOGRAPHY AND RESEARCH

INTERCRYSTALLINE FRACTURE IN STEEL. By D. Hanson, *Transactions* of the Faraday Society, Vol. 17, Part 1, Page 91.

Several examples of intercrystalline fracture in cold worked low and medium carbon steel and quenched carbon steels are given. In the cold worked steels corrosion may have played some part in the cracking but the main cause in all of the cases was excessive internal strains. The article is illustrated with numerous photomicrographs.

THE MECHANISM OF THE FAILURE OF STEEL UPON AND AFTER HARDENING. By G. W. Green, *Transactions* of Faraday Society, Vol. 17, Part 1, Page 139.

The causes of stressing and subsequent failure suggested are: (a) Increased volume change; (b) decreased molecular mobility; (c) instability due to incomplete phase change and the presence of residual austenite; (d) variable volume change due to heterogeneity; and (e) the tendency to warp on quenching due to contraction of the outer skin.

CONSTITUENTS OBSERVED IN TUNGSTEN AND MOLYBDENUM STEELS. By A. Portevin, *Revue de Metallurgie*, Vol. 18, Page 713.

A critical metallographic inspection is made of annealed tungsten steels containing carbon 0.1 to 0.4 per cent and tungsten 5.0 to 7.5 per cent. As a result of this inspection, four constituents are identified, an iron tungstide, a carbon tungstide, a troostite of tungsten and a complex ferritic Fe_2W constituent. Attention is called to the resemblance between the constituents of tungsten and molybdenum steels.

THE COLLOIDAL STATE IN METALS AND ALLOYS I—MOLTEN METAL. By J. Alexander, *Chemical and Metallurgical Engineering*, Vol. 26, Page 54.

The relation of the colloidal state to the "amorphous" state in metals is pointed out and evidence obtained in the ultramicroscopic study of glass is applied to metals.

THE COLLOIDAL STATE IN METALS AND ALLOYS II—CRYSTALLIZATION. By J. Alexander, *Chemical and Metallurgical Engineering*, Vol. 26, Page 119.

This second article takes up the phenomena of crystallization and plastic deformation from the colloidal standpoint.

RESEARCH IN THE STEEL INDUSTRY. By J. A. Mathews, *Mining and Metallurgy*, No. 180, Page 11.

The function of the research laboratory is outlined and research programs discussed. Numerous instances of the value of research in the steel industry are given from the author's personal experience.

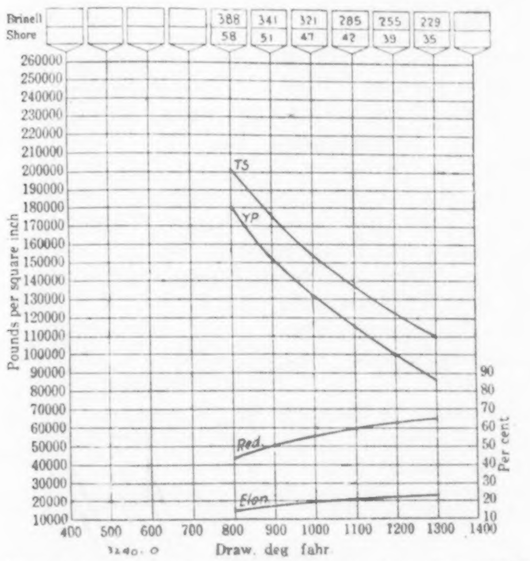
PHYSICAL PROPERTIES OF STEEL

EFFECT OF TIME IN REHEATING QUENCHED MEDIUM-CARBON STEEL BELOW THE CRITICAL RANGE. By C. R. Hayward, D. M. McNiel and R. L. Presbrey. Presented at the February meeting of the American Institute of Mining and Metallurgical Engineers.

Bars of 0.44-0.48 per cent carbon steel were water quenched from 850 degrees Cent. and drawn for periods ranging from five minutes to four hours at temperatures varying from 300 to 600 degrees Cent. Five minutes at 300 degrees Cent. was sufficient to make perceptible changes in the strength and hardness of the metal. Tempering at 400-500 degrees Cent. increased the ductility without lowering the strength the same relative amount. One hour heatings seem to be long enough to accomplish the tempering completely and even 30 minutes is sufficient at 400 degrees Cent.

FRACTURE TESTS ON CONSTRUCTION STEEL AND THE KRUPP "DAUERSCHLAGPROBE." By F. Rittershausen and P. Fischer. *Stahl und Eisen*, Vol. 41, Page 221.

As a result of approximately 3500 tests, a relationship was established between the capacity for resistance in the Krupp machine and the yield point. Tests were made on plain carbon, nickel, nickel-chrome, manganese and silicomanganese steels.



Physical property chart of S. A. E. No. 3240 quenched in oil

REPORTS OF DIVISIONS OF STANDARDS COMMITTEE. *Journal of the Society of Automotive Engineers*, Vol. 9, Page 383.

In the report of the Iron and Steel Division, (pages 392-422) in addition to proposed changes in specifications, valuable information on the effect of heat treatment on the physical properties of the following steels is given: 1020-1045, 2320-2340, 3120-3140, 3220-3250, 3325-3335, and 3435-3450. The information is given in charts a typical one being shown. Information on heat treatment and uses is also given on steel 5120-5150, 5210, 6120-6195 and 9250-9260.

THERMOCOUPLES

LIFE TESTS OF PLATINUM; PLATINUM-RHODIUM THERMOCOUPLES. By C. O. Fairchild and H. M. Schmitt, *Chemical and Metallurgical Engineering*, Vol. 26, Page 158.

Tests made on American and English noble metal thermocouples showed that they deteriorated noticeably when exposed to temperatures of 1250 to 1450 degrees Cent. The English couple was more at fault in this respect than the American. Experiments showed this variation to be due to volatilization of impurities, especially iron. Samples of English thermocouples tested at a later date and made of purer material showed a marked improvement in ability to withstand deterioration at high temperatures.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

AMES, HARVEY C., (Jr-2), 217 Birchwood Ave., Davenport, Iowa.
BALDWIN, R. C., (M-2), Stanley Rule & Level Co. New Britain, Conn.
BECHNELL, EDWIN, (Jr-2), 202 Second Avenue Moline, Ill.
BEEBE, G. E., (S-2), 1231 West Ninth St., Cleveland, O.
CAMPION, D. C., (M-12), 5003 Holcomb, Detroit, Mich.
DAHLEN, JOHN, (M-11), 1807 South Fifth St., Rockford, Ill.
DIETRICH, F. E., (Jr.-2), 2915 Eleventh Avenue, Moline, Ill.
DOERR, PAUL C., (A-2), 54 Meridith Street, Springfield, Mass.
DREVER, HORACE, (M-2), Electric Furnace Construction Co., Philadelphia, Pa.
EGEBERG, BIRGER, (M-3), Stavanger Electro, Staalverk, Stavanger, Norway.
GAILLARD, S. G., (M-2), American Pulley Co., Philadelphia, Pa.
HIGGINS, GEORGE H., (M-1), Burd Ring Co., Rockford, Ill.
HIGGINS, RAYMOND L., (M-2), Mahr Mfg. Co., Minneapolis, Minn.
HOENSHEID, ANTHONY, (M-11), Detroit Twist Drill Co., Detroit, Mich.
HOPPELL, GEORGE C., (M-1), 5142 Spruce Street, Philadelphia, Pa.
LEWTON, ROSS E., (M-2), Studebaker Corp. Plant 2, South Bend, Ind.
LOVE, W. D., (A-2), Atlas Crucible Steel Co. Philadelphia, Pa.
MACKINTOSH & HEMPHILL CO. (S-2) Pittsburgh, Pa.
MCTURK, M. H., (M-2), 314 Penna Bldg., Philadelphia, Pa.
MESTA MACHINE CO., (S-2), Pittsburgh, Pa.
MORIN, L. H., (M-2), Soss Mfg. Co., Grand Ave. & Bergen St., Brooklyn, N. Y.
NOLING, M. N., (M-1), 2004 E. State St., Rockford, Ill.
PECK, C. A., (M-2), 316 E. Monroe St,, South Bend, Ind.
PHILLIPS, ARTHUR., (M-1), Yale University, Hammond Laboratory, New Haven, Conn.
RALSTON, A. L., (A-2), 1734 Lafayette Blvd., Detroit, Mich.
RICHARDSON STANLEY A., (M-2), Madison & Robey Streets, Chicago, Ill.
RITTS, H. L., (M-1), 6545 Epworth Blvd., Detroit, Mich.
ROWAN, HUGH, (M-1), 178 Northwestern Ave., Milwaukee, Wis.
RUBY, WM. J., (M-2), 2174 E. Warne Avenue, St. Louis, Mo.
SPADE J. H., (A-2), Ludlum Steel Co., Philadelphia, Pa.
ST. LOUIS PUBLIC LIBRARY, Olive 13th & 14th St., St. Louis, Mo.
STITES, S. T., (M-1), 623 Oak Street, Rockford, Ill.
STOKES, F. J., (M-1), Tabor Rd. & Cedar Grove Sta., Philadelphia, Pa.
STUMPF, G. A., (M-2), 210 Smith Ave., Lansing, Mich.
SULLIVAN, JOHN H., (M-1), Chicopee High School Chicopee, Mass.
SWENSON, C. E., (M-1), Tarkington Motor Co., Rockford, Ill.
THELEMAN, R. T., (Jr-2), 242 Hancock Ave., Davenport, Iowa.
TITUS, W. E., (A-2), 316 North Third St., Philadelphia, Pa.
TURNER, JOHN J., (M-2), 128 Chandler St., Worcester, Mass.
TUTHILL LEROY M. (M-3), 546 Adams Ave., Scranton, Pa.
UNITED ENGINEERING & FOUNDRY C., (S-3), Pittsburgh, Pa. Attention of F. C. Biggert, Jr.
VOLKOFF, VLADIMIR, (Jr-1), 199½ Eight Street, Troy, N. Y.
WALDRON R. E., (M-2), 5033 Vancouver Ave., Detroit, Mich.
WILLIAMS C., (M-2), 432 West Penna St. Germantown, Pa.

CHANGES OF ADDRESS

BARTLETT, J. W., (M-5)—from Dunn Edge Tool Co., Oakland, Maine, to 596 Jarnis St., Toronto, Ont., Can.
BAYLESS, RAY T., (M-1)—from Jas. H. Herron Co., to 2185 Edgewood Rd., Cleveland, Ohio.
BELIAEFF, S. S., (M-1)—from U. S. High Speed Steel & Tool Co., Green Island, N. Y., to P. O. Box 44, Troy, N. Y.
BLUMBERG, HARRY—from Illinois Steel Co. to 1424 W. 14th St., Chicago, Ill.

BOYER, S. H.—from 1065 Hubbard Ave. to Studebaker Corp., Detroit, Mich.
BRETSCH, A. W., (M-12)—from 1234 Hamilton Ave. to 1234 Harding Ave., Detroit.
BROOKS, CHAS. A., (M-6)—from 2139 Gilles St., Wilmington, Del., to 1393 Broadway, Rennselaer, N. Y.
BURRILL, PERCY J., (A-11)—from 114 Arlington St. to 44 Lincoln Apts., Youngstown, Ohio.
BURROUGHS, J. T., (A-3)—from 3063 West Blvd., to 4329 W. 23rd St., Cleveland.
CALER, J. H.—from Vanadium Alloys St. Co., to 414 Union Bldg., Cleveland.
COLEMAN, JOHN J.—from 79 Adelaide St. W. to 449 St. Paul St. W., Montreal, P. Q., Canada.
CONNER, WM. G., (M-4)—from N. 11th St., Rochelle, Ill., to DeKalb, Ill.
DANIELS, F. C. T., (M-2)—from Beech Glen, Wheeling, W. Va., to R. D. No. 4, Elm Grove, W. Va.
DEMPSEY, H. B., (A-8)—from 253 Broadway to 21 Park Rd. W., New York City.
DISNEY, J. A., (A-12)—from 1326 E. Woodbirdge St. to 10201 E. Jefferson Ave., Detroit, Michigan.
GILTINAN, D. M., (M-12)—from 27 Dunbar St. to 1223 Virginia St., Charleston, W. Va.
GRANGER, D. J., (M-1)—from 1518 S. 48th Ave. to 4725 W. 15th Pl., Cicero, Ill.
GREEN, C. T. M., (M-2)—from A. Hankey Co., Rochdale, Mass., to 100 Burks St., Easton, Pa.
HANDY, H. E., (M-3)—from Washington Steel & Ore Co., Washington, D. C., to 773 Elmwood Avenue, Providence, R. I.
HAYDOCK, JOHN, JR., (M-9)—from 111 Broadway, New York City, to Niles Bement Pond Co., Pond Works, Plainfield, N. J.
HENLEY, W. A., (M-12)—from U. S. N. O. P. S. Charleston, W. Va., to Woodstock, Md.
HODGE, E., JR., (A-2)—from Pittsburgh Knife & Forge Co., Pittsburgh, to Box 466, Coraopolis, Pa.
HOLLERITH, C. B., (M-11)—from 3515 N. Penn Apt., to 20 W. 34th Apt F., Indianapolis, Ind.
HOWLAND, J. A., (A-4)—from 635 Waveland Ave., Chicago, to 555 Beaufait Ave., Detroit, Mich.
HOWLAND, WM. A., (M-1)—from 1217 Maple Ave. to 1316 Lake St., Evanston, Ill.
HUMMELL, A. S., (M-4)—from Bloomsbury, N. J., to 122 N. Third St., Easton, Pa.
KRONFELD, G. L., (M-12)—from 1321 Oliver Bldg., to Vulcan Crucible Steel Co., 493 Union Arcade, Pittsburgh, Pa.
MAGILL, B. H.—from American Locomotive Co. to 103 Nott Terrace, Schenectady, N. Y.
MERRIOTT, WALLACE, (M-11)—from Weekes-Hoffman, Inc., to New Process Gear Corp., Syracuse, N. Y.
MOORE, J. W., (A-4)—from 1404 Oliver Bldg., Pittsburgh, Pa., to Hoskins Mfg. Co., 1445 Laughlin Avenue, Detroit, Mich.
PARDEE, H. A., (M-12)—from Crucible Steel Co. of America, Pittsburgh, Pa., to Box 11, Grand Central Station, New York City.
PEDERSEN, P. P.—from 4126 Zenith Ave. to 4917 S. York Ave., Minneapolis, Minn.
RILEY, ROBT., (M-3)—from 6 Atwood St. to 11 Priscilla Ave., Olneyville, Sta., Providence, R. I.
ROBINSON, S. R., (M-4)—from Sandusky Foundry & Mach. Co. to 409 W. Washington St., Sandusky, Ohio.
SCHMID, M. H., (M-1)—from United Alloy Steel Corp. to 501 11th St. N. W., Canton, Ohio.
SEAMON, W. M., (M-10)—from 41st & Willow St. to 2334 Buxonia Ave., Pittsburgh, Pa.
SHERMAN, A. H.—from 120 Broadway to Industrial Specialties Inc., 52 Vanderbilt Avenue, New York City.
SOWDER, STANLEY, (M-3)—from 6546 Second Blvd. to 80 Davenport St., Detroit, Mich.
STRANAHAN, L.—from Standard Parts Co. to Cleveland City Forge & Iron Co., E. 45th & Lakeside, Cleveland, Ohio.

SURTEES, ROBT. E., (M-2)—from 1622 Hazelwood Ave. to 2919 Anderson, Detroit, Mich.
THOMAS, R. W.—from 74 S. Meade St. to 519 Carey Ave., Wilkes Barre, Pa.
WELLMAN, V. M.—from 1105 Chester Ave. to 1224 Oregon Ave., Cleveland, O.
WHITE, F. G., (M-11)—from Y. M. C. A. to the University Club, Grand & Washington Avenues, St. Louis, Mo.
WILKINS, CHAS., (M-3)—from 4001 Drexel Blvd. to 833 E. 65th St., care Mr. Stinchfield, Chicago, Illinois.

MAIL RETURNED

ALBERS, L., JR., 175 Bleecher St., Brooklyn, N. Y.
ALLEN, R. D., (M-3), Lab. Studebaker Corp., South Bend, Indiana.
MORGAN, A. B., (M-12), 107 Columbia Avenue, Charleston, W. Va.
NELSON, JOHN, Royal Oak, Michigan.
SEMONS, FRANK, (M-4), Spring Perch Co., Stratford, Conn.
SMITHIES, M. W., (M-3), Atlas Ball & Co., 4th & Glenwood Sts., Philadelphia, Pa.
TISDALE, N. F., (M-3), 47 Johnson Street, Springfield, Mass.
WILLIAMS, R. W., (M-8), Sheldon Axle & Spring Co., Wilkes Barre, Pa.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Wednesday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

ROCKFORD CHAPTER

THE *B-C-A News* published monthly by and for the employes of Barber-Colman Co. has a very interesting account of the activities of the Rockford Chapter in the February number. It is as follows:

"Heat treating as an art has been practiced for several thousand years; its importance in industrial operation is of more recent date and seems to be closely connected with the development of the automobile. Whatever the causes of its prominence are or may be, one fact stands out pre-eminent: the seriousness with which the subject is deliberated upon in literature in societies connected with the art and not the least in industry itself.

"The progress of heat treatment is nothing short of astonishing. Once it was an obscure not to say dark art, guarded with great secrecy and passed on only by word of mouth. Today science is its staunchest ally and the practice of heat treating is regulated by organized facts to a point of precision.

"As is the case of any progressive art, not all artisans are able to keep step with the rapid development. Realizing this fact it occurred to a group of men who were actively engaged or connected with the art, that they should unite and with combined efforts venture into an educational campaign for the betterment of the art and its practice.

"These first, although not exactly feeble, attempts proved to be steps in the right direction and developed later on in what is known today as "The American Society for Steel Treating," an organization comprising over 3000 individual members and over 30 chapters located in all parts of the United States, with headquarters in Cleveland, Ohio.

"One of the youngest chapters in the national organization was founded recently in Rockford and is known as the Rockford Chapter of the American Society of Steel Treating. O. T. Muehlemeyer is chairman, O. H.

"These with the board of directors, Charles Cotta, A. H. Hemering, C. R. Crain and John F. Frederick are the officers.

"The first regular meeting was held in December at the Nelson hotel with an attendance of about 100 representing almost the entire steel using industries of the city of Rockford. W. H. Eisenman, National Secretary, was the speaker of the occasion. His subject 'Heat Treating, its Past, Present and Future,' very aptly delivered, held the audience from start to finish and caused many to apply for membership. Previous to the meeting Mr. Eisenman visited our plant.

"The second or January meeting was featured by O. T. Muehlemeyer's paper on 'Hardening Practice,' which was very friendly received. In the course of this paper it was pointed out that the public accepts automobiles, airplanes, sewing machines, cash registers and thousands of other commodities as accomplished facts without thinking much, if any, about the important part heat treating plays in their manufacture. Later on, equipment and operation of a heat treating plant was described more in detail. That this paper was nontechnical made it all the more interesting and, hopefully, serves as an instance for further efforts.

"The third meeting will be held this month—on the thirteenth of February, to be exact—and will be, as we are confidentially informed, of more than passing interest. Two speakers, one of them F. P. Gilligan, President of the National Society, have kindly consented to make their appearance before the Rockford public and judging by past experiences a large audience is to be expected. The active membership of the local chapter has so far reached 50 with one sustaining member, the Barber-Colman Co.

"The society has lately published a small pamphlet, 'A Successful Society for Successful Men,' from which are copied the following paragraphs:

"The purposes of the American Society for Steel Treating are: 1. To promote the arts and sciences connected with the heat treatment of steel, and the study of subjects relating to manufacture, properties and the uses of iron and steel.

"2. To hold meetings in the chapters of the Society—at present there are 32—for the reading and discussion of papers bearing upon processes, instruments, equipment, apparatus, etc., employed in practical and research work connected with the art.

"3. To collect, publish and disseminate technical and practical knowledge for the improvement of conditions in connection with heat treatment of steel.

"4. To closely unite those engaged in the executive, technical and practical branches of the same.

"5. To collect worth-while ideas and improved methods for its members.

"A worthy object, worthy of the best efforts of all interested in steel and its uses, may the Rockford Chapter live and blossom into fulfillment of these high ideals."

SOUTH BEND CHAPTER

The South Bend Chapter held its February meeting on Tuesday, Feb. 14 at the Y. M. C. A. A dinner meeting was held honoring F. P. Gilligan, National President.

The first speaker was Pat Dwyer, engineering editor of *The Foundry*. Mr. Dwyer spoke for one hour and kept the house in an uproar by rapid fire yarns, intermingled with real foundry dope.

The next speaker was Mr. Gilligan whose subject was "What Happens

to Steel When it is Quenched." It would be difficult to really express the appreciation of Mr. Gilligan's lecture. It was far above anything the chapter has yet heard and it was brought home to the shopmen who are still talking about it.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held the fourth of its series of meetings on "The Manufacture, Treating, and Testing of Steel" in the Battery building of the Bethlehem Steel Co., Bethlehem, Pa., on Feb. 13. This meeting featured two subjects: "Castings" and "Forgings."

H. G. Walton of the Bethlehem Steel Co. gave the talk on castings, describing foundry practice from the making of the patterns to the cleaning and inspecting of the finished castings. Mr. Walton discussed the characteristics of various alloy steel castings, the different methods of melting for pouring, etc., the heat treating of castings and gave a list of many types of castings and their uses.

F. P. Martin, superintendent of the forge and heat treating departments of the Ingersoll-Rand Co., and a member of the executive committee of the Chapter gave the talk on forging. Mr. Martin's talk dealt with modern forge shop practice in general. Particularly interesting was the description of the forging of drills or drill steels used for rock drilling.

Both talks were very well presented and it was apparent that both speakers were thoroughly at home with their subjects. Much interest was shown, as usual, in the exhibit, maintained by the Bethlehem Steel Co. at the Battery building and this alone was considered worth the effort in attending the meeting.

TRI-CITY CHAPTER

The regular January meeting of the Tri-City Chapter was held on Jan. 26 at the Davenport Chamber of Commerce. F. P. Gilligan, National President of the Society, gave a very interesting talk on the subject "Quality First," in use and the hardening of tool steel. Mr. Gilligan made his talk very plain, first explaining the subject in metallurgical terms and then in plain English so everybody could understand it. After Mr. Gilligan's talk there was practically no discussion because he had explained everything so thoroughly that there was nothing to discuss. His talk was illustrated with slides.

Motion pictures of the manufacture of steel for sheets and plates, from the Bureau of Mines, Pittsburgh, Pa., were next shown. These pictures were of great interest to all of the members present.

The February meeting of the Tri-City Chapter was held at the Davenport Chamber of Commerce on Feb. 17 when John F. Keller, professor of metallurgy, Lewis Institute, Chicago, presented a paper on "Steel, its Selection and Treatment." This interesting illustrated lecture also included the demonstration of the spark method of selecting iron and steel on a live emery wheel. The meeting was considered one of exceptional value and created a large amount of discussion.

DETROIT CHAPTER

The first meeting of the Detroit Chapter was held in the Board of Commerce rooms on Feb. 13. A round table discussion on ring gears was the principal topic of the evening and created extensive comment and discussion. The questions sent out from the National Office for the "Question

Box" were also presented and discussed. Some interesting discussion resulted.

The second meeting of the month was held on Feb. 27 at the same place. F. H. Helrigel of the Motor Products Co. presented a paper on "Working Sheet Steel." Mr. Helrigel has made a very extensive study of this phase of the subject and had a very interesting paper.

W. P. Woodside, Executive Chairman of the Convention Committee, has made announcement of the assignments of the committee to handle the details of the Convention. These committees appear on another page of this issue of TRANSACTIONS.

NORTH WEST CHAPTER

The fourth lecture in the educational course on the elements of metallurgy and heat treatment being conducted by the North West Chapter was given on Monday evening, Jan. 30 in the rooms of the Manufacturer's Club. Chester S. Moody, Minneapolis Steel & Machinery Co. discussed "Cast Iron" and L. H. Berry, Western Crucible Steel Castings Co., discussed "Cast Steel." Briefs of these lectures, summarizing the issues presented by the speakers, were ready for distribution that evening.

PHILADELPHIA CHAPTER

The February (Big) meeting was held on Friday evening, Feb. 24 at the Engineers' Club. The speakers were National President F. P. Gilligan, Dr. John A. Mathews, president Crucible Steel Co. of America, Pittsburgh, and Richard Spillane, *Philadelphia Public Ledger*. The complete write-up of this meeting will be published in the April issue of TRANSACTIONS.

BRIDGEPORT CHAPTER

The Bridgeport Chapter held a very fine meeting at the Chamber of Commerce on Tuesday, Jan. 31. The first speaker of the evening was C. M. Blackman, foreman, of the heat treating department of the Colt's Patent Firearms Mfg. Co. A. H. d'Arcambal, metallurgist, Pratt & Whitney Co., Hartford, Conn., also presented a paper.

About 65 members and guests were in attendance and practically all of them participated in the discussion which followed the presentation of the excellent papers.

SYRACUSE CHAPTER

S. D. Marshall of the Endicott Forge Co. addressed the Syracuse chapter at its February meeting at Yates Hotel on the subject of "Drop Forgings." Mr. Marshall's wide experience in this line as well as his ability to present his subject in an interesting manner made the meeting a very successful one. A buffet luncheon was served at the close.

RHODE ISLAND CHAPTER

The February meeting of the Rhode Island Chapter was held in the rooms of the Providence Engineering Society on Feb. 12. The speaker of the evening was R. H. Schaffer, superintendent of the Textile Finishing Machine Co., Providence, R. I. He chose as his subject "Practical Hardening Room Practice." Mr. Schaffer was the first representative of a Providence firm to address the chapter and the excellent manner in which he presented his subject and the amount of discussion created was highly pleasing.

CHARLESTON CHAPTER

Fifty-five members of the Charleston Chapter assembled at the Kanawha

Hotel on Feb. 7 and heard a very interesting paper by A. F. Mitchell on "Heat Treatment of Carbon Steel." A lively discussion took place on Mr. Mitchell's paper as well as a discussion on the manufacture of tool steel.

CHICAGO CHAPTER

The Chicago Chapter held its regular meeting on Feb. 9 when they entertained the National President, F. P. Gilligan, who gave an illustrated talk on "Steel and Its Properties." The lecture was presented in a most practical manner and was very pleasing to the 200 members and guests in attendance.

The next meeting will be held on March 9 and will be devoted to the discussion of practical questions. Prof. John F. Keller, consulting metallurgist and professor of metallurgy at the Lewis Institute, Chicago, will open the discussion with some original ideas on "Why Steel Warps."

ST. LOUIS CHAPTER

The February dinner and meeting of the chapter was held at Hotel Claridge on Friday, Feb. 10. The speaker of the evening was W. R. Chapin, director of the testing department of E. C. Atkins & Co., Indianapolis, upon the subject "Properties of Some Steels in the Hardening Range." Mr. Chapin's excellent presentation of the subject was most thoroughly enjoyed by all present. The paper is published elsewhere in this issue of TRANSACTIONS.

BOSTON CHAPTER

The Boston Chapter enjoyed one of the best meetings it has had for some time at the Boston City club on Feb. 10. The paper of the evening was presented by Z. L. Sault, treasurer of the New England Annealing & Tool Co. on the subject of "Heat Treating Experiences." Mr. Sault spoke in a very interesting manner upon the experiences he had encountered and gave those present the benefit of his extensive knowledge and dealing with all kinds of steel.

BUFFALO CHAPTER

The Buffalo Chapter had its regular meeting in the rooms of the Buffalo Engineering society, Iroquois Hotel on Wednesday, Feb. 15. The National President, F. P. Gilligan presented a paper which proved to be especially interesting, and the amount of discussion brought forth was decidedly satisfactory.

WASHINGTON CHAPTER

The February meeting was held in the auditorium of the New Interior Department building on Feb. 17. Francis B. Foley, metallurgist, Bureau of Mines, Minneapolis Station, Minneapolis, Minn., was the speaker of the evening and spoke on "The Annealing and Hardening of Steel." Mr. Foley covered the fudamental relations that must be considered in the annealing and hardening of steel. This involved the means of practical application of the theories of heat treatment and was illustrated by some of the speaker's own investigations into the effect of methods of heat treatment as applied to various materials.

CINCINNATI CHAPTER

The Cincinnati Chapter held a splendid meeting at the Ohio Mechanics

Institute on Feb. 14. Prof. H. F. Moore of the University of Illinois, Urbana, Ill., presented his paper on "The Fatigue, or Progressive Failure of Metals." Approximately 125 were in attendance, the members of the local section of the American Society of Mechanical Engineers being present by invitation.

WORCESTER CHAPTER

The January meeting of the Worcester chapter was held at the National Metals Trades association on Jan. 31. J. C. Spence superintendent of the machine division of the Norton Co. was the speaker of the evening and chose as his subject "Grinding of Steel." Mr. Spence discussed the difficulties encountered in grinding steel; proper methods of procedure; precautions; various grades of finish; grinding cracks, and their cause and avoidance.

The Worcester Chapter held its regular meeting on Feb. 14 in the Y. M. C. A. building. The first speaker of the evening was Z. L. Sault, treasurer of the New England Annealing & Tool Co. of Boston, Mass., and also the secretary of the Boston Chapter. Mr. Sault took as his subject "The Experience of 30 Years in the Heat Treatment of Steel," which included methods for annealing, hardening and heat treating carbon tool steel, high speed steel and low carbon steel for pack hardening. Mr. Sault's talk was a very practical one and met with most general approval of all present.

The second speaker of the evening was F. J. Evans of the Surface Combustion Co. on the subject of "Heat Application." Mr. Evans pointed out that one of the most essential factors, if not the most essential factor, in the heat treatment of steel is the furnace, or the means of heat application. Too often the furnace has been looked upon as merely an enclosure of fire-brick with a fuel—any fuel—applied at some point. He pointed out that accurate heat treatment was absolutely dependent upon correct heat application which means a furnace designed and equipped along engineering principles.

SPRINGFIELD CHAPTER

On Feb. 4 the members of the Springfield Chapter and its friends visited the Springfield Armory plants where the famous Springfield army rifle is made. Mr. Woods, metallurgist at the armory was in charge of the visitation and certainly made the trip a real treat.

The regular February meeting of the Chapter was held at the Chamber of Commerce rooms on Friday evening, Feb. 17. J. C. Spence, works manager of the Norton Co., Worcester, Mass., gave a very interesting and instructive talk on "The Grinding of Tools and Other Heat Treated Materials." Mr. Spence told briefly of the history of grinding and then of some of the troubles encountered in daily practice giving the reasons and cures for them. He also showed a number of lantern slides of various grinding machines, both regular and special.

At the close of the talk an informal discussion was held around a large table on which Mr. Spence showed a large number of interesting samples. About 50 members and friends were present, which was encouraging inasmuch as the meeting was held on the coldest day of the year.

CLEVELAND CHAPTER

The Cleveland Chapter held its regular meeting at the Cleveland Engineering Society's rooms, Hotel Winton, Friday evening, Feb. 24. The paper of the evening was presented by Francis B. Foley, of the Bureau of

Mines, North Central Experiment Station, Minneapolis, Minn., on the subject of "Industrial Pyrometry." Mr. Foley has done extensive research work in pyrometry and his talk was full of practical suggestions and interesting details.

The March meeting will be held on March 31, on the same date as the meeting of the nominating committee. The members of the committee have consented to present short talks before the chapter. D. W. McDowell, chief inspector of Jones & Laughlin Steel Co., and secretary of the Pittsburgh Chapter will speak on the "Testing of Steel Plates." W. J. Priestley, superintendent of the United States Naval Ordnance Plant, Charleston, W. Va., and chairman of the Charleston Chapter will present an illustrated talk showing slides of the plant and various methods of manufacture of armor plate. Chester S. Moody, metallurgist of the Minneapolis Steel & Machinery Co. and the first chairman of the Northwest Chapter will present a paper on a "Tractor Gear Problem." H. C. Goodwill, superintendent of dies, R. Wallace & Sons Mfg. Co., Wallingford, Conn., and chairman of the New Haven Chapter will speak on the subject of "Hardening of Dies." Carl Schumann, mechanical engineer, Miehle Printing Press & Mfg. Co., Chicago, and former secretary of the Chicago Chapter will speak on the "Relationship of the Mechanical Engineer to the Laboratory."

TORONTO CHAPTER

The Toronto Chapter of the society held its February meeting on Feb. 16 in the Mining Building of the University of Toronto. F. P. Gilligan, president of the Society presented an illustrated lecture on steel that met with quite hearty approval by the large number in attendance. W. H. Eisenman, National Secretary, was also present and gave an outline of the progress the society has made during the past year.

SCHENECTADY CHAPTER

The regular meeting of the Schenectady chapter was held on Tuesday evening Feb. 28 in the metallurgical laboratory of the American Locomotive Co. J. V. Emmons, National Treasurer of the American Society for Steel Treating, and metallurgist of the Cleveland Twist Drill Co., Cleveland, presented an illustrated lecture on "Effect of Structure Upon Machining of Tool Steel." Mr. Emmons' entertaining lecture was very highly appreciated and enjoyed.

As a special added feature explanations and demonstrations as to how steel is tested were given. The entire equipment of the metallurgical laboratory was operated for the benefit of members and friends of the society. There was a demonstration of how steel is analyzed, how the physical measurements are obtained, the effect of etching and how microphotographs are taken. Altogether the evening was a decided success.

HARTFORD CHAPTER

At the January meeting of the local chapter, held on Jan. 5 in Hartford, H. J. French of the Bureau of Standards, Washington, described the purposes of the bureau and some of the problems which the bureau has worked out. Investigations of the strength of steels at temperatures higher than atmospheric, and the heat treatment of molybdenum steels were described at some length, and slides and motion pictures illustrating the equipment and some of the activities of the heat treatment section were shown.

Dr. R. W. Woodward, formerly of the Bureau of Standards, but now metallurgist with the Whitney Mfg. Co., told of a somewhat uncommon effect he had observed in the heat treatment of chain links recently. A single lot of links which came through the regular heat treatment showed a blistered surface, as though badly scaled. Examination proved that only a very slight superficial scale was present, however. Evidence obtained by a thorough investigation indicated that the atmospheric conditions in the furnace that produced the blistered links were at fault, in that the flame was not sufficiently reducing in character.

At this meeting sets of samples were given out to various members and visitors to be heat treated to get certain properties. These heat treated samples will be returned to the Stunt Night Committee at the February meeting. Tensile tests, etc., which cannot be conducted easily at a regular meeting, will be made on the specimens during the following month, and the results will be ready for publication at the Contest meeting in March. At this meeting it is proposed to test all the specimens by means of the scleroscope, Brinell test, and Rockwell test. The committee has promised to have a good supply of inspection files present, and the various ideas of "file hardness" of the different members will be compared. It is also hoped to have one of the new Stacks spark testers in operation. This meeting will not only serve as a competition between rival heat treaters, but will also serve to show the man at the fire how his product is being checked up in his own inspection department and by the consumer.

In order to lighten the serious aspect of this meeting, certain of the samples distributed bear no identifying marks, so that the person by whom they are received has no idea of the composition of the steel. The results obtained on these dark horses should provide a lot of fun. A box of cigars is offered as a prize to the competitor who receives the greatest number of points for his work.

The regular February meeting of the Hartford Chapter was held on Feb. 9, in Jewell Hall of the Hartford Y. M. C. A. The attendance at the meeting was about 120, of whom about 50 were members, the remainder guests. The speaker of the evening was A. H. d'Arcambal, of the Pratt & Whitney Co., Hartford, and his subject was "High Speed Steel." Mr. d'Arcmabal has spoken on the same subject at national conventions and before various chapters of the Society, and his talk on this occasion was an abstract of the material which he has presented heretofore in his various talks, with additional data developed in recent tests. Specimens of tools showing proper and improper treatment were exhibited, and the reasons for failure or success of each treatment were discussed. Specimens of the two common types of high speed steel, that is, 14 and 18 per cent tungsten steels, were shown with fractures after treatment and soaking at various temperatures.

From Mr. d'Arcambal's tests it appeared that the grain of the 14 per cent tungsten type coarsened more rapidly than the 18 per cent under the various treatments, in other words, it is a more sensitive steel, and must be handled more carefully. Cutting tests, however, showed that the lower tungsten steels stood up in service somewhat better than those containing 18 per cent tungsten. One interesting chart showed the Brinell, scleroscope, and file hardness of high speed steel quenched from various temperatures plotted simultaneously with the same properties for the same steel quenched at the same temperatures, but drawn back at 1100 degrees Fahr. It was observed that for quenching temperatures below 2300 degrees Fahr., the specimens

drawn at 1100 degrees were softer than the quenched and undrawn specimens. At 2300 degrees Fahr. and higher, the specimens retained their original hardness. This appears to vindicate the proponents of the higher quenching temperatures, that is, 2300 degrees Fahr. and higher, also the exponents of the high draw. Considerable discussion of the paper ensued, in which the desirability of carbon content in excess of 0.65 per cent was emphasized.

After Mr. d'Arcambal's paper, specimens heat treated by various members were collected to be surface ground and otherwise prepared for testing at the March meeting. This meeting will be a Heat Treatment Contest, and specimens prepared by the committee and heat treated by different members and guests will be tested by the various modern methods of inspection applied to heat treated products. It is anticipated that the tests will cause a great deal of fun, and it is probable that there will be some difficulty in awarding the prize. The contest committee, however, wish to have it known that they "are boss," and what they say, goes.

Mr. Curran described some recent work of W. R. Chapin, on the "Properties of Steel in the Hardening Range," or the range between Ac_1 and Ar_1 which has been lowered by quenching from above Ac_1. Test pieces were exhibited, which had been quenched from above the critical range but removed from the quenching bath in the range 800 to 1200 degrees Fahr. While at this temperature, the Rockwell hardness and file hardness were relatively low, and the specimens could be bent easily and otherwise deformed. When subsequently quenched into oil at about 300 degrees Fahr., however, the specimens were file hard, and showed a Rockwell hardness characteristic for the steel quenched cold in the usual way.

The list of meetings for the remainder of the season is as follows:

March 10:—Heat Treatment Contest. Everyone is invited to compete for the prize.

April 13:—"The Characteristics of Tool and Alloy Steels," by Dr. John A. Mathews, President Crucible Steel Co., Pittsburgh.

April 29:—9:00 a. m., Inspection of New Departure Co. Plant Britol, Conn., Courtesy of the New Departure Co. All New England Chapters of American Society for Steel Treating and American Society of Mechanical Engineers are invited.

May 11:—"The Inspection and Heat Treatment of Steel," by J. J. Curran, The Henry Souther Engineering Co., Hartford, Conn.

June 8:—Annual Banquet. Speakers to be announced later.

In additioon to the subjects announced above, some time will be devoted each evening to:

1. "Question Box;" 2. Short reviews from current literature on steel treating and equipment; and 3. Some unique heat treatment effects observed by members.

NEW YORK CHAPTER

At the regular January meeting of the New York Chapter held in the Engineering Society's building on Wednesday evening, Jan. 18, some 80 members and guests assembled to hear a very excellent paper by A. W. F. Green, metallurgist, John Illingsworth Steel Co., Philadelphia. Mr. Green presented an illustrated lecture on "Annealing." He took particular care to impress upon his hearers the difference between "full annealing" and "partial annealing," the first accomplished at temperatures above the critical, and the second at temperatures just below the critical. He presented a number of lantern slides showing how the theory of the process was borne out by observation of the finished pieces, after undergoing treatment of both kinds. An animated discussion followed.

In a brief period devoted to current events in metallurgy mention was

made of the completed work on the fatigue of metal, and the discovery of a rapid method for determining the endurance limit; work which has been going on at the University of Illinois under the direction of Prof. H. F. Moore.

The regular February monthly meeting of the Chapter was held on Wednesday, Feb. 15, in the assembly room of the Merchants Association of New York. The room has been very generously tendered to the section for its regular use, and is conveniently situated in the Woolworth building. Located as it is at the focus of the rapid transit systems of the Metropolitan District, this meeting place seems to solve the question "Where can we meet where it will be convenient to our widely scattered mmbers?"

S. P. Rockwell prepared a paper on carbonizing practice, but unfortunately was unable to attend owing to sudden and serious illness in his family. Captain Walter C. Graham read his paper, and made it doubly interesting by a critical commentary on the subject, prompted by his own very thorough knowledge. About sixty members were in attendance.

Commercial Items of Interest

THE American Engineering Standards Committee has just completed arrangements by which co-operation with the standardizing bodies in other countries will be made more effective. In doing this, it has followed out the recommendations of the unofficial conference of the secretaries of the national standardizing bodies held in London in April, 1921.

In order that all standards shall be available to the industries of the various countries, it is planned that each national body will sell the approved standards of the other bodies. The American Engineering Standards Committee, 29 West Thirty-ninth street, New York, has available the publications of the standardizing bodies in Austria, Belgium, Canada, France, Germany, Great Britain, Holland, Sweden and Switzerland.

Hereafter the American Engineering Standards Committee will exchange regularly information with the foreign bodies as to the status of work on the various projects being undertaken under its auspices. This information will be limited to the indication of the stage of development of the projects, it being left in each case to the various sectional committees and sponsor bodies to decide to what extent they desire to exchange technical memoranda or drafts of standards. This exchange of information on the general progress of the work will lay the basis for closer international co-operation as the need for this develops in special instances.

Installation of 67 double frame drop hammers at the Highland Park plant of the Ford Motor Co., Detroit, now being effected, is the first important step by the Ford organization in its plan to do practically all of its own drop forging work under its own roof. At the present time, practically all of this work, which is enormous, is let out to numerous companies. These 67 hammers will bring the total hammer equipment of the Ford company to 100. The new hammers range from 800 to 5000 pounds and are being placed in operation immediately upon being set up. It is expected it will be several months before all are in operation.

Detroit has been selected as the meeting place of the National Safety Congress to be held Aug. 28 to Sept. 2, inclusive, under the auspices of the National Safety Council, Chicago. A local committee to handle the preliminary details relative to the meeting has been named with S. C. Mumford, president of the Detroit Safety Council, as chairman.

Announcement is made of a new edition of *Hendricks Commercial Register of the United States*, a 2324-page listing of business organizations published by the S. E. Hendricks Co., Inc. By way of review *The Iron Trade Review* says:

"The 1922 edition of this book differs from those of previous years in that the size has been changed in the interest of readability. The new

type size is 7 x 10 inches and more space has been allowed between lines and columns. In spite of the fact that the enlarged page accommodates 25 per cent more subject matter, the number of pages has not been decreased proportionately.

"As in former editions, the book covers a wide range of industries and lists the manufacturers of equipment under many headings, including electrical, engineering, machinery, building, manufacturing, chemical, hardware, iron and steel, railroads, mining, quarrying, architectural, etc. Dealers, manufacturers, producers, and consumers are registered. At least 100,000 names of individuals and companies are classified by trades or products, and are indexed and cross indexed. A separate section furnishes references to distinctive products, listed by trade names or special brands. In another section the names of manufacturers are arranged alphabetically and their addresses and principal products are given.

"Primarily the book is intended to be a guide for buyers and sellers and to this end the descriptive information of products and services is expected to assist in locating the sources of and outlets for finished materials."

Wilson-Maeulen Co., 383 Concord avenue, New York, announces that Carl E. Hellenberg, with headquarters at 231 California avenue, Detroit, has been appointed the company's representative for Michigan and northwestern Ohio. Mr. Hellenberg has had much practical experience in both hardness testing and pyrometry and he will take care of the company's interests regarding both its direct reading hardness testers and pyrometers.

Effective March 1, the St. Louis office of the Chicago Flexible Shaft Co., Chicago, manufacturers of flexible shaft machinery, and gas and oil furnaces, will be resumed. J. J. Wittenburg, who has been in the Chicago office of the company for three years, will be in charge. As previously, the St. Louis office will be located in the Railway Exchange building.

Joseph H. Roberts, superintendent of the bar steel and special products department, Nicetown works of the Midvale Steel & Ordnance Co., has resigned to accept the position of assistant to L. J. Campbell, president of the Electric Alloy Steel Co., Youngstown, O.

The American Society for Testing Materials, 1315 Spruce street, Philadelphia, has recently published its proceedings of the twenty-fourth annual meeting held at Asbury Park, N. J., June 21-24, 1921. It contains 1198 pages, 6 x 9 inches, and is bound in cloth. By way of review, *The Iron Trade Review* says:

"This volume of *Proceedings* contains committee reports, new and revised tentative standards, and technical papers presented at the last annual meeting of the American Society for Testing Materials. The meeting is briefly summarized in the first part of the book and the president's annual address and the report of the executive committee are given in full. The next section is devoted to reports of committees including those on ferrous metals; nonferrous metals; cement, lime, gypsum and clay products; and miscellaneous materials. Tentative standards submit-

ted at the 1921 annual meeting are published, including those pertaining to ferrous metals; nonferrous metals; cement, lime, gypsum and clay products; preservative coatings; petroleum products and lubricants; road materials; coal and coke; insulating materials, shipping containers; textile materials; and miscellaneous subjects. Twenty-four technical papers, a list of society officers and members of the executive committee and an index complete the book.

Beginning with 1922, the engineering division of the American Railway Association and the Association of American Steel Manufacturers became member bodies of the American Engineering Standards Committee. The Association of American Steel Manufacturers is an organization of 40 iron and steel manufacturing companies. Its activities are limited to the standardization of rolling mill practices, and to the standardization and inspection of iron and steel products. The association was organized in 1895. Its official representative on the American Engineering Standards Committee has not yet been designated.

The American Railway Association, which speaks for practically all the steam railways of the country, has four great technical branches, each having its own secretary. The engineering division, which is intimately connected with the American Railway Engineering Association, the two organizations having the same officers, covers broadly the civil engineering activities of the railways. These two new member bodies bring the total number of national organizations represented upon the American Engineering Standards Committee up to 28, and of representatives to 52.

Eastern representatives of the Thomas Buchanan Co., Cincinnati, manufacturer of a case hardening compound, has been placed with the F. A. Calhoun Co., Lincoln Trust building, Jersey City, N. J.

Within a few days the President is expected to affix his signature to the Lampert bill and afford that relief for the patent office which engineering societies have been seeking for months. As passed by the senate, the Lampert bill provides 48 additional employes for the office and increases salaries, the theory being that an enlarged and more efficient

(*Continued on Page* 35)

ADDITIONAL EMPLOYMENT SERVICE ITEMS

POSITIONS WANTED

METALLURGIST—Eight years experience in research, metallography, heat treatment, complaint and service work; High speed, tool steel and cast cutter work. Address 3-30

TOOL HARDENER OR FOREMAN—30 years earnest effort in tool forging and tool hardening with extensive high speed steel experience. Can offer efficient operation or supervision. Exceptionally successful in eliminating scrap—Excellent references, Location immaterial. wages desired $50.00 per week. Address 3-40

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths. Best of references. Reasonable salary. Address 3-15.

STEEL EXPERT—Heat treatment, metallurgy. A graduate in chemistry and iron and steel manufacture. Six years laboratory experience. Desire position in production department. Can make good. Present salary ($3000.00) Ordnance man, Navy Department. Will consider ($2000.00) as a start if there are good prospects. Address 3-10

FOREMAN HEAT TREATMENT—16 Years experience on armor plate gun forgings and all kinds of heavy forgings and castings; carburizing, research, testing and experimental work including design operation and erection of all types of heat treating furnaces. Age 32. Married. Address 3-5.

CHEMIST-METALLURGIST—Experienced in making steel casting, all processes. Am a practical foundry man, steel blower, and chill roll maker. Have been Supt. of large foundry. Best of References. Age 40. Married. Address 3-2.

POSITIONS OPEN

STEEL SALESMAN—To cover Northern Ohio. Must have had selling experience and thoroughly familiar with high speed and carbon tool steels. An excellent opening for someone who can produce results. Address 3-10.

(*Continued from Page 33*)

personnel will shortly clear up the years' accumulation of business. To make up the additional cost, the initial fee to be paid on application for a patent is increased from $15 to $20. The secondary fee remains at $20. The estimated increased revenue from this advance in the primary fee is $500,000 annually. Steps are being taken by T. E. Robertson, patent commissioner, to enlarge his staff at the earliest possible moment.

George H. Clapp has retired as president of the Pittsburgh Testing Laboratory, Pittsburgh, and has been succeeded by Col. James Milliken. Mr. Clapp continues as a member of the board of directors.

The Alfred O. Blaich Co., manufacturer of carbonizing material, announces removal from Chicago to its new plant at 555 Beaufait street, Detroit.

George J. Hagan Co., Pittsburgh, furnace and combustion engineers, recently has opened up offices in Detroit and Chicago. The Detroit office is located at 515 Murphy building and is under the management of J. Sandberg, formerly with the General Electric Co. The Chicago office, located at 20 E. Jackson boulevard, is in charge of V. A. Hain, also formerly connected with the General Electric Co.

The Federal Supply Co., East Seventy-ninth street, Cleveland, has been appointed representative of the Quigley Furnace Specialties Co., Inc., 26 Cortlandt street, New York.

Time Study and Job Analysis is the title of a new 397-page book by William O. Lichtner, published by the Ronald Press Co., New York. By way of review *The Iron Trade Review* says:

"The purpose of this book is to show in detail how to standardize production. It is a text book written by an able consulting engineer in management and construction, in simple and nontechnical terms; a plain and coherent explanation of the subject as might be given in a series of conferences with an executive charged with the responsibility of decision.

"In chapters I to VI a general review is given of the principles of job standardization and their application to the methods of time study and job analysis. In chapters V to VII the organization of a staff to carry out the work is discussed in detail from the point of view of the executive. In chapters VIII to XX a detailed description of the technique is given. This portion of the book especially may be used as a textbook and guide in an actual development of time study and job analysis in a particular case. In this part emphasis is placed upon applications of the technique described to the permanent needs of a plant. In chapters XXI to XXII job standardization is considered in its relation to industrial problems.

" 'A matter which the engineer must consider,' " says the author in his preface, " 'is the relation of job standardization to planning of the work from the inception of the order to the delivery of the finished product. Sometimes the improvement in planning precedes, sometimes it follows the work of standardization; but in any case the success of standardization is closely bound up with the methods by which the product is routed in the factory from process to process. Furthermore, inasmuch as pay and conditions of

work—the two greater factors in the labor situation—are materially improved by time study and job analysis, the work of standardization has proved of great importance in connection with labor relations. Finally, even sales policies are affected by job standardization.' "

An evening course in metallography has been inaugurated by the Polytechnic Institute, 99 Livingston street, Brooklyn, N. Y. Instruction is given by lectures and laboratory practice in a well-equipped metallographic laboratory. The course covers a study of the microstructure of iron and steel and its fundamental physical chemical principles. The course consists of 15 lectures given on Friday evenings at 6:30 and 15 two-hour laboratory periods on Friday or Monday evenings from 7:30 to 9:30 beginning Feb. 3. The fee is $25 and the membership is limited to 30.

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